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# SCHOOL SCIENCE AND MATHEMATICS

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## THE SUPPLEMENTARY PROJECT IN MATHEMATICS.


BY CHAS. A. STONE,

*University High School, University of Chicago.*


A survey of the literature dealing with the term project reveals a lack of uniformity as to its meaning. According to some teachers any effort toward giving their work a practical turn is termed a project. Some use the term where simple laboratory exercises are undertaken, while others use the word for a mere motivating technique.

For many years the term project was used to designate carefully planned investigations in agricultural science covering a considerable period of time, frequently demanding several years for their completion. C. W. Stone defines the term as a "Life Topic" in which the processes and objects of learning are largely manual while French[1] thinks of it as a home project, under careful supervision by some competent person, applied to instruction in elementary and secondary agriculture.

The latter approaches the modern conception of the project method in that the project is related to the work in school, and that it is necessary to keep careful records and submit a carefully written report of same. The plan fails, however, in being narrowed to the field of agriculture. Likewise if the supervision tends to destroy the original ideas of the pupil it is a detriment rather than an aid.

According to Woodhull,[2] the project method is the normal method of growth by means of which related material is interpreted and then classified into life's experiences. He further states that supplied with appropriate materials, the child uses them for his own development and effects his own organization. The child also desires to interpret situations having certain

[1] Report of Agriculture in the High Schools of Michigan, 1916.

[2] The Aims and Methods of Science Teaching. General Science Quarterly, Vol. 2, November, 1917.

values when confronted with them. This conception seems to include all intellectualized effort, which is put forth because of the students' voluntary, purposeful, attitude toward the solution.

Another definition encountered states that a project is a concrete problem outlined sufficiently fully and clearly to enable the student, for whom it is designed to carry it out. One from the standpoint of Physics thinks of it as a problem the solution of which results in the production of some object, or knowledge of such value to the worker as to make the labor involved seem worth while. Still another by an English teacher maintains that a project is a complete unit of purposeful instruction. Thus we see that the word project has been limited, by some people to a purposed activity of considerable complexity and difficulty, while other people have used the term to include every type of intellectual activity whether simple or complex, difficult or easy. The writer is of the opinion that this confusedness is nothing more than the consequence of trying to specialize a common general term.

In this discussion, however, the project will be defined in terms of intellectual interests. It is not considered a part of the classroom procedure, although it is an aid in the teaching process where supervised study is an essential part of the teaching technique. The general theory of instruction contemplates supplementary studies by pupils both as evidence of intellectual interest and trained study capacity.

These supplementary studies are termed supplementary projects. Thus the broader meaning of the term is accepted since it is true that the difference between a simple intellectual difficulty and a complex intellectual difficulty is relative and that these difficulties in reality are aspects of the same type of mental development.

The supplementary project, therefore, is the undertaking of an investigation which aims to train the student in the higher study capacities, that is, particularly in the ability to use such resources as the library and bodies of uncompiled material. It is of such a nature that it grows definitely out of the work of the course that the student is carrying, or is related to it. If only remotely related to the foundation study the so-called project is not of any value and is really a distraction rather than an aid in producing intellectual ability.

As the project looms up before the student he moves forward or grows in grappling with the material. Through the project

the pupil relates himself to the knowledge that is not a part of himself, but knowledge that is within his reach. He plunges out, so to speak, into a world different from his own and returns with valuable experiences. These experiences become a part of him and he is now better equipped for more complex interpretations. It is through this method of growth that he develops, and if sufficient material properly related to his world is furnished, and if he is keenly interested, rapid growth is inevitable.

Now it is true that we may not be able to get more than a thoroughly good and well done composition from some pupils. These, however, are acceptable if the students grow out of this type of activity and progress, and as they grow older their papers represent real investigations rather than merely descriptive accounts of the things they have read.

Furthermore the investigation should be one that represents a real interest on the part of the pupil and should be a voluntary undertaking. All of the illustrations such as drawings tending to clear up the subject matter should be the pupil's own work. As was previously stated the investigation was to be necessarily related to the work of the class. Therefore it is essential that the ground-work or class-work be thoroughly mastered before the pupil is allowed to attempt a piece of independent work.

**UNIVERSITY HIGH SCHOOL**
**Department of Mathematics.**
**Supplementary Reading Report.**

Name of Pupil..... Math..... .....

Date..... ..... Period..... Time Spent..... .....

Author..... Title..... .....
Book or Magazine

Topic..... .....

Chapter..... Pages..... .....
Report:

FIGURE 1

Keeping these points in mind, let us now proceed to the technique of carrying on the supplementary project work. One of the brighter boys of the freshman class was able to master thoroughly the minimal essentials required in a unit of work in a much shorter period of time than his classmates. He was assigned a number of difficult problems related to the unit in

question, but was nevertheless able to do these without a great deal of exertion, and finished them in a very short time. Here evidently was a student of the superior type, capable of carrying on some investigation that would train him in the higher capacity of study. The problem before the instructor was to get him interested of his own free will and accord in some topic for study, without having the instructor make an assignment. To carry out this plan the boy was given the blank shown in (fig. 1) and was told to report to the library to do some profitable reading during the mathematics period, and report on same the next day. The blank was designed by Mr. Breslich of the mathematics department and is used by all instructors. All that is necessary to admit the student to the library is this blank accompanied by the signature of the instructor on the margin on the left hand side of the sheet. The next day the boy returned to class with a report on the "Lives of Great Mathematicians." This showed that he was becoming interested and the instructor was confident that before long he would select some topic for investigation. He was told that he would be released from the routine of regular classroom work until the class completed the unit, and that he would be vigorously examined on the units work and on the results of his study. He then asked if he might select some topic and submit a carefully written report of the same. This request was granted and without the assistance of anyone he worked up a paper on "Mathematical Inheritances." While this paper was well written it was nothing more than a good composition not at all representative of the work that this student was capable of doing and did not tax his intellectual powers. Thus when he inquired about some more supplementary work he was assigned the investigation of the topic "The Origin and Development of Our Present Method of Extracting Square Roots of Numbers." When the investigation was completed it was presented to the class by the student.

This served as a stimulus to the better students of the class, as, not wishing to be outdone in scholarship or intellectual attainment by any of the classmates, they came forward and asked that they be permitted to work on some project. Not only were the good students aroused, but some of lower ability became interested and wished to do some of this work. They were told, however, that this was impossible until they had completed the minimum essentials in the unit. The result was that they

attacked their daily work with renewed vigor and zeal. One boy in particular who was slow in his class work but otherwise a very conscientious pupil selected a topic during one of his study periods in the library in spite of the fact that he was advised not to attempt any extra work. Much to the surprise of the instructor this pupil brought in some results that he had obtained in trying out some of the suggestions given in an article entitled "War Problems in Mathematics."

In another class a ninth grade boy who was excused from the routine of class work, had been reading chapter one of Whitehead's "Introduction to Mathematics." In his report he stated that he was very much surprised to learn that mathematics and science dealt with real things of every day life. He further stated that henceforth he would take a different attitude toward these subjects. Likewise an eighth grade boy who was sent to the library became interested in the general properties of the equation. This boy was engaged in reading Burnside and Panton's "Theory of Equations." His report was full and fairly comprehensive.

A tenth grade boy selected for his reading "The Fourth Dimention Simply Explained," by Manning. His report discussed the logic employed in the reasoning presented by the author, and he also considered the difficulties in the imagery of the fourth dimension. As a result of this reading the boy was induced to write a paper on the above topic. In the same class a girl made a short report of what she did in thirty-five minutes in reading chapter 1 of Conant's "Exercises in Geometry." Her statement is as follows: "I worked on a problem after finishing the first theorem. The problem was—The lines drawn from either pair of opposite vertices of a parallelogram to the mid-points of the parallel sides lying opposite the vertices from which they were drawn, trisect the diagonal connecting the other pair of vertices." This was a good start toward getting this girl interested in a supplementary project and during the year she completed several investigations. The following report was made by a third year girl and is given in full.

University High School
Department of Mathematics
Supplementary Reading Report Sheet

| | |
|---|---|
| Ruth Norman | Mathematics III |
| January 23, 1924 | Fifty minutes |
| Arthur Schultze | Advanced Algebra |

Determinants of the Fourth Order

| | |
|---|---|
| Chapter XXVII | Pages 409-413 |

By performing certain operations, the formula for the expansion of a determinant of the fourth order is obtained.

$$\begin{vmatrix} a_1b_1c_1d_1 \\ a_2b_2c_2d_2 \\ a_3b_3c_3d_3 \\ a_4b_4c_4d_4 \end{vmatrix} = a_1\begin{vmatrix} b_2c_2d_2 \\ b_3c_3d_3 \\ b_4c_4d_4 \end{vmatrix} - a_2\begin{vmatrix} b_1c_1d_1 \\ b_3c_3d_3 \\ b_4c_4d_4 \end{vmatrix} + a_3\begin{vmatrix} b_1c_1d_1 \\ b_2c_2d_2 \\ b_4c_4d_4 \end{vmatrix} - a_4\begin{vmatrix} b_1c_1d_1 \\ b_2c_2d_2 \\ b_3c_3d_3 \end{vmatrix}$$

Similarly, expansion in terms of $b_1c_1$ and d may be obtained.
Example of expansion:

To expand:
$$\begin{vmatrix} 4 & 2 & 1 & 1 \\ 1 & 0 & 2 & 3 \\ 2 & -1 & 2 & 0 \\ 3 & 2 & 0 & 1 \end{vmatrix}$$

$$-1\begin{vmatrix} 2 & 1 & 1 \\ -1 & 2 & 0 \\ 2 & 0 & 1 \end{vmatrix} + 0 - 2\begin{vmatrix} 4 & 2 & 1 \\ 2 & -1 & 0 \\ 3 & 2 & 1 \end{vmatrix} + 3\begin{vmatrix} 4 & 2 & 1 \\ 2 & -1 & 2 \\ 3 & 2 & 0 \end{vmatrix}$$

$$= -1(1) + 0 - 2(-1) + 3(3)$$
$$= -1 + 2 + 9 = 10$$

The above reports are typical of the many that are turned in during the year and as previously stated furnish an excellent method of getting the pupil interested in some extensive piece of work. Frequently the student will enlarge on one of the topics reported in the supplementary reading and will spend several weeks or months, in working up an excellent paper as a supplementary project. All good papers are neatly bound and placed on the library shelves for use by other students, as this serves as an excellent stimulus to the other pupils to do a similar or better piece of work. A few of the great number of projects handed in during the year are as follows:

1. The Use of Graphs.
2. An Odd Method of Determining the Year of Birth.
3. Supplementary Exercises on The Theorem of Pythagoras.
4. The Bahai Temple.
5. Finding square root on the adding machine.
6. Extension of a process of Factorization.
7. Vormarios of us FZero and Unity.
8. Problems in Heights and Distances.
9. Geometry in Sculpture.
10. Euclid Dramatized.
11. Pythagoras.
12. The Squaring of the Circle.
13. The Fourth Dimension Explained by Geometry.
14. The Survival of the Mystical Mathematician.
15. Magic Squares.
16. Bolshevick Mathematics.
17. A Mock Mathematical Trial.
18. Mathematics in Verse.
19. Mathematical Ignorances.
20. Extracting Square Root on the Typewriter.

It might be mentioned at this point, however, that all pupils are not capable of carrying on an investigation independently of the teacher and thus need the latter's advice during the time that work is being done on the project. It is frequently neces-

sary to be very specific in the selection of the topic and careful instructions are needed to make sure that pupils understand what is expected of them. Thus definite texts where they may find the topic are mentioned, and frequently with pupils of the Junior High School definite page references must be given. The pupils' task then is to weave together the facts as he finds them into a coherent composition.

To carry on an investigation in mathematics is more difficult than in most other subjects. In English and History, for example, there is ample provision for wide supplementary reading that is within the pupils' powers of comprehension. It is possible in these fields that an enterprise might originate with the pupils themselves, as it frequently happens that during the study of a unit there is some phase not covered by the minimum essentials which might arouse special interest and lead to a special investigation. Pupils in reading articles and books dealing with mathematical literature, however, are confronted with symbols and discussions with which they become acquainted in the more advanced courses only. Thus we find a number of pupils attempting projects that they are unable to work out and after hours of fruitless work they become discouraged and choose a project that represents little if any intellectual effort. There is not at present a great variety of mathematical literature which can be read and understood by pupils of the high school age and such material as they can assimilate is being prepared by the writer with the aid of the department of mathematics at the University High School. Most of the projects that are being collected appear in the books and journals listed below. Copies of these books should appear in every high school library.

Summing this discussion we see that the supplementary project has the following advantages:—

1. It arouses and gratifies mental curiosity and intellectual interests
2. It introduces pupils to the work of the scholar.
3. It promotes intellectual achievement and enriches life.
4. It contributes to an appreciation of learning.

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American Mathematical Monthly.

## A NEW NUMBER SYSTEM.

By H. C. Christofferson,

*Normal School, Oshkosh, Wisconsin.*

Just as our English unit of measure—one foot—was the length of some English king's foot, and a yard the distance from the end of his nose to the tips of his fingers, so our number systems, both the Roman and Arabic, have as a base ten units, corresponding to the ten fingers of our hands.

There is no reason for the selection of this base. The selection was purely a convenient accident. Before there was a number system, before the race knew how to count with figures, people used to count with a tally or on their fingers. Through the long process of evolution it is generally conceded that the presence of the ten digits on our hands is probably the sole factor determining ten for the base of our present counting system.

Scientific research has determined a system of measurements, the metric system. In many ways it is far more convenient than the English system. It is a decimal system so that reducing to a smaller unit or a larger unit is merely a process of moving the decimal point. For instance .5647kg. = 564.7 grams. 4.759m = 475.9 cm. In the English system, reducing pounds to oun ces or yards to inches is much more complicated. Whether or not the English system will ever be completely replaced in the United States by the Metric system is a question time will decide. The fact remains, however, that the metric system is superior in organization and more efficient to use.

An analysis of our number system shows an even greater deficiency. Ten is not a convenient base. Its only factors are two and five. Twelve would be far more convenient as a base. 1/2, 1/3, 2/3, 1/4, 3/4, 1/6, 5/6, of 12 can be readily computed, while only 1/2, 1/5, 2/5, 3/5, 4/5, of ten can be readily computed. Furthermore, thirds and fourths are used far more often than fifths. The advantage then of seven integral fractional parts as compared with only five becomes more sinificant. With multiples of the new base the advantage will be far greater, in fact it will be squared or cubed in the square or cube of the base. No woman ever buys a fifth of a yard, but frequently a purchase is made with thirds or fourths. Therefore the advantage to a merchant in computing sales would be considerable.

Let us construct such a system of numbers. It will be necessary to coin two words as the names of the two added digits. For efficiency these words should be short and as different as

possible from our present numbers. An analysis of our present number names shows that none of them use the vowels a or u, nor the consonants l, g, z, m. These names are suggested as the new numbers to follow nine,—"lug" and "zam," and the symbols for them "L" and "Z." Our twelve digits would then be zero (0), one (1), two (2), three (3), four (4), five (5), six (6), seven (7), eight (8), nine (9), lug (L), zam (Z).

The following table shows how the new and old systems would compare. The symbols selected to represent the new digits are not the best, but are selected for convenience in printing.

COMPARISON OF OLD AND NEW NUMBER SYSTEMS.

| Old | New | Old | New | Old | New | Old | New | Old | New |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 41 | 35 | 81 | 69 | 121 | L1 | 288 | 200 |
| 2 | 2 | 42 | 36 | 82 | 6L | 122 | L2 | 432 | 300 |
| 3 | 3 | 43 | 37 | 83 | 6Z | 123 | L3 | 576 | 400 |
| 4 | 4 | 44 | 38 | 84 | 70 | 124 | L4 | 720 | 500 |
| 5 | 5 | 45 | 39 | 85 | 71 | 125 | L5 | 864 | 600 |
| 6 | 6 | 46 | 3L | 86 | 72 | 126 | L6 | 1008 | 700 |
| 7 | 7 | 47 | 3Z | 87 | 73 | 127 | L7 | 1152 | 800 |
| 8 | 8 | 48 | 40 | 88 | 74 | 128 | L8 | 1296 | 900 |
| 9 | 9 | 49 | 41 | 89 | 75 | 129 | L9 | 1440 | L00 |
| 10 | L | 50 | 42 | 90 | 76 | 130 | LL | 1584 | Z00 |
| 11 | Z | 51 | 43 | 91 | 77 | 131 | LZ | 1728 | 1000 |
| 12 | 10 | 52 | 44 | 92 | 78 | 132 | Z0 | 15552 | 9000 |
| 13 | 11 | 53 | 45 | 93 | 79 | 133 | Z1 | 17280 | L000 |
| 14 | 12 | 54 | 46 | 94 | 7L | 134 | Z2 | 19008 | Z000 |
| 15 | 13 | 55 | 47 | 95 | 7Z | 135 | Z3 | 20736 | 10000 |
| 16 | 14 | 56 | 48 | 96 | 80 | 136 | Z4 | 186624 | 90000 |
| 17 | 15 | 57 | 49 | 97 | 81 | 137 | Z5 | 207360 | L0000 |
| 18 | 16 | 58 | 4L | 98 | 82 | 138 | Z6 | 228096 | Z0000 |
| 19 | 17 | 59 | 4Z | 99 | 83 | 139 | Z7 | 248832 | 100000 |
| 20 | 18 | 60 | 50 | 100 | 84 | 140 | Z8 | 497664 | 200000 |
| 21 | 19 | 61 | 51 | 101 | 85 | 141 | Z9 | 2,223,488 | |
| 22 | 1L | 62 | 52 | 102 | 86 | 142 | ZL | | 900,000 |
| 23 | 1Z | 63 | 53 | 103 | 87 | 143 | ZZ | 2,488,320 | |
| 24 | 20 | 64 | 54 | 104 | 88 | 144 | 100 | | L00,000 |
| 25 | 21 | 65 | 55 | 105 | 89 | 150 | 106 | 2,737,152 | |
| | | | | | | | | | Z00,000 |
| 26 | 22 | 66 | 56 | 106 | 8L | (Old) | | (New) | |
| 27 | 23 | 67 | 57 | 107 | 8Z | 2,985,984 | | 1,000,000 | |
| 28 | 24 | 68 | 58 | 108 | 90 | 29,859,840 | | L,000,000 | |
| 29 | 25 | 69 | 59 | 109 | 91 | 32,845,824 | | Z,000,000 | |
| 30 | 26 | 70 | 5L | 110 | 92 | 35,831,808 | | 10,000,000 | |
| 31 | 27 | 71 | 5Z | 111 | 93 | | | | |
| 32 | 28 | 72 | 60 | 112 | 94 | | | | |
| 33 | 29 | 73 | 61 | 113 | 95 | | | | |
| 34 | 2L | 74 | 62 | 114 | 96 | | | | |
| 35 | 2Z | 75 | 63 | 115 | 97 | | | | |
| 36 | 30 | 76 | 64 | 116 | 98 | | | | |
| 37 | 31 | 77 | 65 | 117 | 99 | | | | |
| 38 | 32 | 78 | 66 | 118 | 9L | | | | |
| 39 | 33 | 79 | 67 | 119 | 9Z | | | | |
| 40 | 34 | 80 | 68 | 120 | L0 | | | | |

The table looks complicated, as would also a metric table giving the English equivalent of each unit and tenth of a unit. Some of its advantages are evident, however.

With a two digit number you can represent a wider range of values. Zamty-zam equals 143. Zam hundred zamty-zam (ZZZ) equals 1727, and Zam thousand zam hundred zamty-zam (ZZZZ) equals 20,735. One thousand according to the old system equals $(10)^3$ and according to the new system $(12)^3$ or 1728, one million equals $(12)^6$ or 2,985,984. It is evident that a much larger value can be represented by a smaller number of digits than in the old system.

A second advantage is far more significant, however, and that is that more fractional parts of one hundred are integral

FRACTIONAL PARTS OF 100.

| Fraction | Old System | New System |
|---|---|---|
| 1/3 | 33 1/3 | 40 |
| 1/6 | 16 2/3 | 20 |
| 1/8 | 12 1/2 | 16 |
| 1/9 | 11 1/9 | 14 |
| 1/12 (1/10) | 8 1/3 | 10 |
| 1/16 (1/14) | 6 1/4 | 9 |
| 1/18 (1/16) | 5 5/9 | 8 |

The table is not complete but merely suggestive. The new base has more factors than ten has and therefore any multiple of that base would have a great many more factors. One hundred in the old system can be divided evenly by 2, 4, 5, 10, 20, 25, 50; one hundred in the new system can be divided integrally by 2, 3, 4, 6, 8, 9, 10, 14, 16, 20, 30, 40, 60, nearly twice as many factors. This shows its greater efficiency and usefulness.

A study of the new multiplication tables is interesting. The new system is used throughout the tables. Remember that the decimal base is 10 which is equal to 12 in the old system.

| Table 3's | Table 8's | Table Z's |
|---|---|---|
| 1 ×3 = 3 | 1 ×8 = 8 | 1 ×Z = Z |
| 2 ×3 = 6 | 2 ×8 = 14 | 2 ×Z = 1L |
| 3 ×3 = 9 | 3 ×8 = 20 | 3 ×Z = 29 |
| 4 ×3 = 10 | 4 ×8 = 28 | 4 ×Z = 38 |
| 5 ×3 = 13 | 5 ×8 = 34 | 5 ×Z = 47 |
| 6 ×3 = 16 | 6 ×8 = 40 | 6 ×Z = 56 |
| 7 ×3 = 19 | 7 ×8 = 48 | 7 ×Z = 65 |
| 8 ×3 = 20 | 8 ×8 = 54 | 8 ×Z = 74 |
| 9 ×3 = 23 | 9 ×8 = 60 | 9 ×Z = 83 |
| L ×3 = 26 | L ×8 = 68 | L ×Z = 92 |
| Z ×3 = 29 | Z ×8 = 74 | Z ×Z = L1 |
| 10×3 = 30 | 10×8 = 80 | 10×Z = Z0 |

| | | |
|---|---|---|
| 11×3 = 33 | 11×8 = 88 | 11×Z = ZZ |
| 12×3 = 36 | 12×8 = 94 | 12×Z = 10L |
| | 13×8 = L0 | |
| | 14×8 = L8 | |
| | 15×8 = Z4 | |

Now you teachers and prospective teachers who think it is easy for a child to learn the multiplication combinations just try to memorize this table of zams, or write the table of lugs. One zam is zam; two zams are lugteen; etc. to nine zams are 83; lug zams are 92; zam zams are lugty-one; ten zams are zamty; eleven zams are zamty-zam; and twelve zams are one hundred lugs. Nothing could seem more nonsensical or uninteresting. How must a multiplication table seem to a little eight or nine year old child? Perhaps not so bad as this seems, but no doubt more meaningless than we often think.

Now what is the value of proposing such a ridiculous thing as a new number system? Surely the writer will not be such a fool as to recommend its adoption? Think of the cost of making the change. Every typewriter, adding machine and other computing machine would have to be radically remodelled or perhaps scrapped. Our money system would have to be made over, the new dollar would be worth 1.44 present dollars, the new dime would be worth 12 cents and there could be 1/2, 1/3, 1/4– and 1/6 dimes in place of only nickels of the present. The metric system would be changed somewhat. A liter would be nearly twice as large as at present.

The tremendous cost of the adoption of this new system makes it entirely impractical. Its only possible practical value would be the development of better appreciation of our present number system, of the difficulties involved in its mastery, and of the possible imperfections of any arbitrarily established system. Aside from this it is purely an impractical dream, a rational but useless theory, and perhaps the best that can be said about it is that it is an interesting speculation.

## SHALL WE MATHEMATIZE OR DEMATHEMATIZE HIGH SCHOOL PHYSICS?

By J. M. Hughes,

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*The question.*—Shall we mathematize or dematheматize our high school physics? This question has come to be one of importance because there is a strong opposition to the tendency to dematheматize the subject.

*The origin of the problem.*—The movement to demathematize high school physics emanated from leaders in the field of physics instruction who had an awareness of a general dissatisfaction toward the results of instruction in the high school. It was the somewhat general belief that this instruction had lost some of its effectiveness through an overemphasis on the technical phases, especially upon those phases involving exact measurement and the use of the more complicated mathematical processes. The following widely cited quotation from Professor Michelson represents somewhat this point of view.

"It is my belief that the teaching of physics might be made far more attractive as well as useful . . . if less stress were placed upon what has come to be regarded by many as its chief object, namely, the science of measurements . . . . I would, therefore, propose for discussion the feasibility of a plan for the teaching of physics which avoids as far as possible the use of mathematics of even the most elementary kind, and which gives to the science of measurement only a secondary importance.[1]"

Other leaders agreed with Professor Michelson and the trend of instruction has definitely taken the direction suggested by them. Just how far the demathematizing movement has progressed would be difficult to determine. It has at least gone far enough to stir up some hostility.

*Present day college teachers oppose demathematization.*—The opposition to demathematization of physics in the high school may be best illustrated by citations from two studies. The first is a study reported by members of the faculty of Western Reserve University; the second is a study reported by Professor Foley of Indiana University but which includes the opinions of teachers of physics in all the colleges of Indiana.

The Western Reserve Study included 238 pupils in physics classes in a large high school of whom 165 were boys and 73 were girls. The pupils were given 14 physics problems to solve, the solutions to which involved a knowledge of mathematics on the part of the pupils. The following are problems typical of the test:

Problem 8. "The density of oxygen at 0 degrees centigrade and 1 atmosphere of pressure is .00143 grams per cubic centimeter. A 100 liter tank contains 715 grams of oxygen. Under what pressure is it at 0 degrees?"

[1]Michelson, A. A. *The Purpose and Organization of Physics Teaching*, SCHOOL SCIENCE AND MATHEMATICS. January, 1909, Vol. IX, 3-4.

Also problem 13 in their list:

"A 3,200 pound automobile starting from rest attains a speed of 90 feet per second in 30 seconds. What is the average force in pounds exerted by the engine?"

The subjects were given forty minutes to see what they could do with the fourteen problems. The following quotation states the views of the authors as to the result.

"Each problem is solved by only 15 per cent of the pupils: no problem is solved by more than 69 per cent, while two straightforward problems are out of the range of every pupil. *This reveals a condition truly surprising.** The extent of the lack of comprehension shown therein of *the numerical relations** of the simplest and most fundamental principles of physics is certainly startling and lends support to the criticism, *often heard, that the average high school student acquires merely a mass of disconnected facts,** with little notion of the underlying and unifying principles. It is clear *that the present method of teaching physics fails of its object** in so far as it attempts to give the pupil any knowledge of the principles which lie back of *common numerical problems.**[2]

A further conclusion of the authors is of interest here.

"In the opinions of the authors, *if anything worthy of the name of physics is to be taught,** this process *of making the subject attractive and easy by dematematizing it must cease.*"*[3]

It is not our purpose here to pass upon the validity of this study. The significant fact is *that the authors voiced a criticism which they probably believed to be held in common by college professors of physics.*

Professor Foley's study included more college professors and more high school pupils. He gave 10 questions which he thought to be representative of subject matter in physics and to be of proper difficulty to 1,058 high school pupils who were entering the classes in physics in the various colleges in Indiana in 1920. He then obtained the opinions from the professors of physics in the colleges in which the tests had been given as to the value of the high school courses in physics.[4] In other words these men were to evaluate the results of the instruction of teachers, most of whom had received their training

*Italics by the writer.

[2]Randall, D. P., Chapman, J. C., and Sutton, C. W. *The Place of the Numerical Problem in High School Physics.* School Review, 26: p. 41, 1918.

[3]Ibid.

[4]Foley, Arthur L. *The College Student's Knowledge of High School Physics.* SCHOOL SCIENCE AND MATHEMATICS. 22:601-12, 1922.

for the teaching of physics in these same institutions. Their opinions are as one. Dr. Foley himself concludes that "the claim that physics can be 'put across' by dealing with practical things is not substantiated by this study." None of the college instructors approved the high school course. Most of them were of the opinion that physics as taught in high schools of Indiana was valueless. In other words, in the opinion of these men, the pupils taking the high school courses in physics were failing to present any evidence of worthwhile achievement. This achievement was measured by ability to solve mathematical problems.

*How much mathematical ability may we expect of the pupils taking physics?* We may reason from the results on the tests used in the Western Reserve Study and by Professor Foley that we should cease "practicalizing" and begin "mathematizing." But the teacher must take the product as it comes to him. The pupil has already been "mathematized." How much of his mathematics can we expect him to use?

The writer gave the following two problems to approximately four hundred pupils who had just completed a year's course in high school physics.

"Two forces of thirty and forty pounds, respectively, act on a point in opposite directions. What is the resultant?"

"Two forces of thirty and forty pounds, respectively, act on a point at right angles. What is the resultant?"

The two problems differ mainly in the mathematical processes involved in their solution. But the introduction of the extraction of the square root in the second problem markedly changed its difficulty. The first problem was solved correctly by 75% of the group, while the second problem was solved correctly by but 49% of the group. If the introduction of a mathematical process which involves a right triangle of 3:4:5 relationship changes the difficulty of a problem by this amount, one may surmise what difficulty is added to the understanding of a principle when the more complicated mathematical processes are made necessary to its understanding. Of course the physics teacher has the privilege of pausing to teach the needed mathematics. Here the time element enters. How much time would he have to take from his teaching of physics to teach the desired skills in problem solving—say the skills required to solve problems as involved as the ones given in the Western Reserve Study?

*Hotz's results.* Hotz found that problems in algebra such

as the following represent the average ability of pupils after they have had nine months of high school Algebra.

(1) $(x+3)/(x-2)=(x+5)/(x-4)$. One-half of 1,608 pupils solved this correctly.

(2) $1/(a-x)-3a/(a^2-x)$. One-half of 1,447 pupils were able to subtract this correctly.

(3) $(c-d)/(c-d)^2\times(c-d)/(c^2+d^2)$. One-half of 1,505 pupils were able to multiply this correctly.

The writer took four problems from Hotz's study and gave them to a class consisting of twenty-six university seniors and graduate students. The mean number of years of training in mathematics of the members of the class was 4.1 years. The maximum was nine and the minimum two.

The following were the problems chosen:

(1) $(1+2)/(x+y) = 1$. Solve for x.

(2) $\sqrt{20}+\sqrt{45}+1/\sqrt{5}$. Combine.

(3) A train leaves a station and travels at the rate of 40 miles an hour. Two hours later a second train leaves the same station and travels in the same direction at the rate of 55 miles an hour. When will the second train pass the first?

(4) A merchant has two kinds of tea, one kind costing 50 cents and the other 65 cents per pound. How many pounds of each must be mixed together to produce a mixture of 20 pounds that shall cost 60 cents per pound?

These problems are missed by from 75% to 97% of high school pupils who have taken one year of high school Algebra. What may we expect from a group of highly selected university students who have had an average of 4 years of training in mathematics? Problem 1 was solved correctly by eight of the twenty-six, problem 2 by seven, problem 3 by seven, and problem 4 by four. The number of years training in mathematics had by the eight students who correctly solved problem 1, was 9, 9, 8, 7½, 6, 4, 3½ and 3½ years, respectively. The seven students who solved problem 2 correctly had 9, 9, 8, 7½, 6, 3½, and 2 years training respectively. The seven students who solved problem 3 were identical with those who solved problem 2. The four students who solved problem 4 correctly had 9, 8, 7½, and 6 years training respectively. These four students also succeeded in solving all of the problems correctly. Eighteen students failed to solve any problems correctly.

Neither the intelligence nor training of the pupils in a high school class in physics is likely to equal the intelligence and train-

ing of the group here tested. In the typical high school the pupils in the physics class will be markedly inferior to them. If this class in the university can not solve the problems here given, it is not likely that we can mathematize the physics in high school to any great extent and get satisfactory achievement. If we consider the pupils primarily, we may be safe in assuming that they may come to us after having a year or a year and a half of high school algebra with the abilities to solve simple algebraic equations. When the teacher expects to use more complicated mathematical processes it may be advisable for him to assure himself in advance on bases other than assumption that the pupils are able to solve the mathematical equations he expects to use. They should really be able to solve readily equations of greater difficulty than he expects to use, as a pure mathematical process becomes more involved when used in situations other than those of a purely mathematical nature. If the pupils are found to be unable to solve complicated problems, it is probably unwise to attempt to teach them the mathematical processes needed. It will be more profitable to be content with a use of simpler processes and to spend the time teaching something other than mathematical processes which the pupils have been unable to learn in a year and a half under specialized instruction.

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**NOTES CHANGED INTO MUSIC WHEN BROKEN UP BY TREES.**

Stories of fairy music in the forest, of haunted waterfalls, and mermaids singing near the seashore, long thought mere figments of the imagination, may have a sound basis in fact. In "Science," Dr. Alexander Forbes of the Harvard Medical School reports numerous cases in which trees seem to have separated discordant shouts and noises and given back echoes in musical tones.

"In every case," he says, "the source of the sound—waves on a beach, roar of a river, exhaust of motor boat or discordant human voices—was one in which many pitches were present. Something in the surroundings, usually trees, must have separated the sounds according to pitch, placing those of one pitch in one place and those of another pitch elsewhere. In this respect the phenomenon appears amalgous to that of white light being broken up into pure spectral colors by a prism."

This reflection or absorption of sound waves of different pitches, Dr. Forbes explains, is only rarely observed. Sometimes the phenomenon is distinct and clear in one spot, yet a few paces backward or forward only the ordinary noises are heard.

The frequent association of trees with these musical echoes is thought to be due to lack of uniformity they present as a reflecting surface for the sounds. Each tree apparently sends back part of the sound, and this reflection is broken up into innumerable parts on account of the varying element of distance.

French engineers are adopting an American invention, and building engines to operate with mercury vapor instead of with steam.

## "PROBABILITIES."

By Joseph M. Synnerdahl

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In this paper, I shall try to give a brief account of the Theory of Probability and a few of its most important applications. Our knowledge of any kind rarely rises to the dignity of a certainty; and yet it is all we have to act upon, and we must generally draw our conclusions from more or less uncertain premises. Where there is the possibility of representing quantitatively with more or lress accuracy the degree of certainty of our premises the Theory of Probability enables us to draw the best conclusion and to estimate its chance of correctness.

Like a number of other sciences, its origin is rather disreputable. The first mention of it is about two hundred and fifty years ago. Two players were interrupted in a game of chance and applied to Pascal for decision as to the equitable division of the stakes—and for one hundred years there was scarecly any other use made of the principles of the science than to reckon chances in gambling games. Now, however, its aid is called in all sorts of cases: in insurance, in discussion of statistics, in support of the Theory of Evolution—in any problem of measurement, where, if absolutely correct the data would be more than sufficient to cover the problem.

Now then, can Mathematics, the science of exact statement, and uncertain conclusion, concern itself with problems where the data are inexact and the conclusions uncertain? Mathematics investigates into the question "how much?" and uncertain frequently submit themselves to more or less accurate measurement. Thus if a die is thrown the chances are five to one against ace coming up; if I draw a ball from a bag containing 7 white and 4 black, the chances are 7 to 4 in favor of white. We have all degrees of probability from almost absolute certainty to almost complete impossibility. We can use mathematics in all cases where chances can be stated quantitatively, and the conclusions we draw are mathematically true, that is, in so far as the original assumptions are true and no farther. Mathematics, like Formal Logic, is a science of necessary deductions from assumed premises. It does concern itself with the premises unless they are self-contradictory.

The great difficulty with questions on the theory of probability lies in stating the respective chances in quantitative terms. When the statement is properly made, the conclusion necessarily

follows, although it may be far different from what is expected.

There are a few general propositions out of which the whole theory grows, and they are simple enough to be understood by anyone. I will give some of them, and illustrate by a few very simple examples. Most of these examples are taken from tossing of coins, or throwing dice, etc.—not at all because the theory finds its principal application in such problems, but these cases are most simple, and the estimation of the probability can be most accurately made.

First we define mathematically the probability of an event by a fraction formed by dividing the numbers of cases favorable to the event by the total possible number of cases. Thus the possible number of cases in tossing a coin is two. Head or tail must be the result; and we say the probability of head is one half and tail is also one half. In throwing a die any one of the six faces may come up. The probability of any specified face is therefore one sixth. We readily see that on this scale measurement certainty is represented by one. If all faces of the die are aces, where the probability of throwing an ace six divided by six, that is a certainty. Impossibility, the other end of the scale of probability, is represented by zero, and therefore all grades between certainty and impossibility are represented by fractions between one and zero.

In ordinary betting language probability is expressed in terms of odds for or against any particular thing. Thus we say that the odds for a particular event are 2 to 1, that is, that of three possibilities two are in favor of the event. In the other way of expression, we say the probability is two thirds. If the odds are 5 to 6 the probability for the event is five elevenths, against the event, six elevenths.

If an event must happen, the sum of the probabilities of the various ways in which it may happen is always equal to unity. Thus if a die is thrown one face must come up, and each face is equally probable. The probability for each face is one sixth and the sum of the probabilities for the separate faces is six sixths or one. If an event must happen, the probability of its happening in any particular way plus the probability of its not happening in that way is always unity. This principle sounds a good deal like a truism, and yet it frequently saves a lot of trouble in computations. For instance what is the chance throwing ace at least once in two throws with a single die? We

may compute as follows: the favorable chances are—ace, not 5 5 1 ace,—not ace, ace,—ace, ace. The total number of chances favorable and unfavorable is 36, that is, any face of the die on the first throw may be followed by any face on the second throw giving in all 36 possibilities. Therefore, the probability of at least one ace in two throws is eleven thirty-sixths. We might solve the problem as follows: since there are five faces not ace on the die there are five times five combinations in which the ace does not appear; hence the probability of not throwing ace in either throw is twenty-five-thirty sixths, and therefore the probability of throwing ace at least once is one minus twenty-five thirty-sixths equals eleven thirty-sixths as before.

Another rule easily deducible from the principle that the probability of an event is equal to the ratio of favorable chances to the total number is that ths probability of a compound event is equal to the product of the respective probability of its components provided these are independent of each other.

The example just cited can be treated according to this rule. The probability of ace, ace, is one-sixth times one-sixth equals one thirty sixth—ace, not ace, one sixth times five-sixths equals five-thirty sixths, etc.

It might be supposed that in three throws it would be an even chance that any particular face would turn up, as it is an undoubted truth that in a great number of throws about will come up for each face. But we see that the chance for one ace (including also the chance for two or three) is only ninety-one two hundred sixteenths less than one-half for three throws, and for four throws it is only a little better than one-half. Note that I have said that the numbers will be equal or approximately so for each face. The two things are very different as I shall show later.

There is another case of compound events which requires a somewhat different treatment. In the case illustrated each throw of the die was entirely independent of the other throws. But suppose one has to compute the probability that a given person will break his leg in a railway accident. Here we have the probability of his taking the train, the probability that train meets with an accident, the probability that he will be injured in the accident, and the probability will be a broken limb. Each of these is dependent on all which precede. He will not break his leg unless he is injured, he will not be injured unless the train meets with an accident, and the accident to the train will not affect him if he does not take that train.

In such a case the rule is that the probability is the continued product of the separate probabilities each in succession being reckoned on the basis that the preceding events have happened.

To take a simpler example, what is the chance of drawing a black and white ball by successive drawings from a bag containing five black and three white balls. the balls not being replaced after the drawings. A black ball may be drawn first, with the probability five-eighths. After the black ball is drawn, then the chance of drawing a white ball is equal to three-sevenths, and the chance of the combination black, white, is five-eighths times three-sevenths equals fifteen fifty-sixths. Or a white ball may be drawn first is three-eighths, and then the chance of drawing a black ball at the second draw is five-sevenths, and the chance of the second combination is three-eighths times five-sevenths equals fifteen fifty-sixths, the same as the first. The sum of the probabilities, first and second, equals thirty fifty-sixths and represents the possibility of drawing a black and a white regardless of order, and is obviously just the same as though the two balls were drawn simultaneously. Total chances are:

$$\frac{8.7}{1.2}$$

Let us now examine the chances of throwing a coin a number of times in succession, or a number of coins all at once, the results will be the same. The chance of getting five heads in eight throws of a single coin is the same as for getting five heads out of a single throwing of eight coins together.

If a single coin is thrown once there is an equal chance for head or tail. If two coins are thrown, they may be both heads, head and tail, both tails, but the chance for second head and tail, is twice as great as for both heads or both tails, etc.

Those of you who remember the Binomial Theorem will perhaps recognize that these numbers are nothing but the coefficients in the series giving the various powers of a binomial, and that the numbers giving the total possibilities are nothing but the successive powers of two.

In case that the chance for any single event is one-half as it is of head or tail in the throw of a coin, but is some other fraction, as for example one-sixth for ace in a single throw of a die, the chance for a given number of aces in any given number of throws is computed by the complete binomial theorem with the literal parts replaced respectively by the chances for and against in a single throw. Thus the chances for two aces in a single throw with six dice will be:

$$_{2}^{6}C\left(\frac{1}{6}\right)^{2}\left(\frac{5}{6}\right)^{4}$$

where the numbers are large the computation becomes laborious, but the results can be obtained with sufficient accuracy by approximation formulas.

In examing the table we find that as the number of trials increases, the numbers giving equality of heads and increase but not as fast as the total number of possibilities so that the chance for an equal distribution diminishes.

We may therefore conclude that the chance is even the most like-number of successes and failures is half the total number, but that the probability of this exact distribution diminishes as the number of trials increases.

When the chance is not one-half but some other fraction it may be proven that the most likely number is given by the product of the probability of the single event by the total number. Thus in 6000 throws of dies, the most likely number of aces is 1000, but the chance that the number is exactly 1000 is very small, and the chance of this exact distribution diminishes as the number of trials increases.

The first part of the conclusion is what everyone would expect and it was perhaps hardly worth while to prove it; but the other part of the conclusion is perhaps so obvious; and as far as any observation goes most people would say that in a great number of trials the numbers of successes and failures would be approximately equal if the chance was an even one, and that these numbers would differ less and less the larger they are. You may not assent to this form of statement, but you would probably say that the statement that a gambler playing a game in which the chances were even would come out in the long run without material loss or gain approximately was correct. Yet the two are precisely the same.

But before going into that question more fully let us consider what deviation from the expected number is probable. It is a rather intricate mathematical problem, but the application is not difficult. If 100 throws of a coin are made the formula gives three as the probable deviation from heads and tails. That is, in 100 trials it is just likely that the number of heads (tails) will lie within the limits 47 and 53 as that they will lie outside of those limits. For 1000 throws the expected deviation is 11; that is, it is an even chance that the numbers will lie within the limits

489 and 511. For 10,000 throws the numbers are 33, 4967, and 5033, etc.

You see that as the number of trials increases the expected deviation also increases, not in the same ratio, but about as the square root of the number.

Suppose we now consider for a few minutes the general subject of gambling from the standpoint of the theory of probability. I do not mean to say anything about the evil results on the specifically moral side, the getting something for nothing, the almost certain squandering of gains, and the ruin brought about by loss—but I wish to say a few words on the point of advantage or disadvantage to the individuals and the community. The ethics I shall introduce are purely utilitarian, and a course of procedure which will in the long run produce an increase of fortune, will be regarded as advantageous, and the contrary course will be disadvantageous.

If two men with equal available capital begin a course of betting with equal advantage on each side for each separate venture, as for instance in tossing a coin, theory shows that in the long run, not that the losses and gains will practically balance, and each keep his capital practically intact, but one or the other will, if the game is continued long enough, absorb all the money. One man will freeze the other out. The even chance is not that each man will come out even in the end, but that one man is as likely as the other to win the whole amount. As far as the final result is concerned it is the same as though they staked their whole fortunes on a single throw. It is merely prolonging the agony to play for small stakes.

It is practically inevitable that as the number of trials increases the greater will be the deviation from the expected distribution. We saw that in 10,000 throws of a coin the probable deviation from equal distribution of heads and tails was 33. If now two men with 30 stakes each play, the chance is less than one-half the game will last through 10,000 trials. One or the other will lose everything before that number of trials is made. The process is not a rapid one, but the result is practically certain.

The advantage of a large capital shows itself very distinctly, in fact it may be shown, that if the game is prolonged and the number of trials large, the relative advantage is proportional to the capital. That is, suppose one man has twice the capital of the other, his chance of being the final possessor of the money is two-thirds. It is two to one that he will break the other

fellow. This is one of the chief factors in the enormous and almost certain profits in the large gambling hells. Their capital is greater than that of the individuals who play against them, and they can stand a longer run of ill luck. There is in almost all games played in such places a small percentage in favor of the bank which also tends to increase the profit, and which is frequently assigned as the chief source of the profit, but I think generally not enough account is taken of the large capital.

A man with large capital may with advantage play against an opponent with smaller capital although the opponent has a slight advantage in each separate trial, but it is a fine example of the perversity of human nature that large gambling concerns can find plenty of men who are willing to stake their money at a game where there is the double chance against them, of the game itself, and the relative disproportion of capital possessed by the player and the bank.

But cannot a man postpone the inevitable by some procedure, as staking a certain proportion of his available funds at each venture. True he would never lose the total as only a part is put up at each trial, but it is easy to see that his march toward comparative beggary is accelerated. Suppose a man always stakes half of his funds—I take an example from Whitworth's "Choice and Chance." Suppose he has $256, and stakes one-half and wins $128. He now has $384. He next stakes $192 and loses, he now has $192, a net loss of $64 for one gain and one loss. If he had first lost and then gained the result would have been the same. For two gains and two losses the net loss would have been $112. The equal distribution of the number of gains and losses works to his disadvantage. Of course the probability of equal numbers of losses and gains is small, but he will get rid of his money or gain the other man's in a much faster way. However, if two men are playing, both of them can not follow this method of play.

The case is something like the following: Suppose one man owes another a dollar, and the debtor proposes to toss a coin for double or quits. That is, if he wins the debt is cancelled, if he loses the debt becomes $2. Mathematically speaking this is an equitable proposal. Suppose the debtor loses and proposes the same wager. He loses and now owes $4. The game goes on until the debtor wins once. The game is ended and the original debt is wiped out. It is evident that such will be the case, and the original creditor has no chance to get his money. He loses

his hold on the debtor the first time the chance goes against him and as the individual risks were equal in all cases, has he any chance of saying that he was unfairly treated?

But it is often argued that everyone can not lose, what is lost by one set of persons must necessarily be gained by some other set and the total result on the property of the community is nil. Well, according to a good many political economists, a transfer of property which means a loss for one party in order to make a gain for another is not economically commendable. Sound trading should mean a gain for both parties.

To my mind the real disadvantage to the community is the undue concentration of wealth in the hands of a few individuals. That this tendency exists as the result of perfectly fair gambling will, I think, be seen from what has been said, and one need not be a socialist or a follower of Bellamy to consider it an evil that most of the wealth should be in the hands of the few, a chance few, not the few who have been trained to use the money, by hereditary influence, or the few who have gained their fortunes by ability of one kind or another, but a few selected by a purely chance process. It seems to me any community would be better off without such fortunes and anything which tends to produce them is in so far disadvantageous.

What is the difference between Insurance and Gambling? In both a certainty is risked against an uncertainty. At the present time there are not many who consider the taking out of insurance policies as an unusual act, but it has not always been so. In the early days of Insurance it was gravely argued that it was betting against Providence, and not a few good people refused to have anything to do with such an unholy act. One does often hear the argument now, yet some still hold that it is in a sense an endeavor to circumvent the Almighty.

In reality, insurance is the reverse of gambling. If I gamble, I exchange a smaller certainty for the chance of a larger uncertainty. In insurance, I pay a small to avoid the risk of a large uncertainty. The risk is already present aside from any act of your own, and insurance enables you to minimize the risk, that is really rids from the necessity of gambling. Suppose you own in one piece, property worth $1000 of such a character that on the average one piece out of every hundred becomes a loss through fire every year. Your expectation from that property is not a thousand dollars but $990. If you can get someone for ten dollars to agree to replace your property in case of fire, or

pay you $1000, you are getting rid of your risk completely, at no cost to yourself. In case of fire, you get the $1,000, which less the insurance is $990, the full value of your expectation. You have by the payment of a small sum of ten dollars, got rid of the gambling feature of your investment. Of course no one, except perhaps a populist legislator, expects an insurance company to do business at such a ratio. Insurance men are not in business for their health. Your mathematical expectation of loss being ten dollars, the insurance will assume that risk for the ten dollars plus the interest on his own capital, the cost of carrying on the business, etc. In many cases the plus no doubt represents a sum larger than the expectation of loss, but I think that the general opinion is that cheap insurance is in the long run the dearest kind. Most men justly conclude that the wiser course is to pay a larger sum than the expectation of the loss, in order to avoid the risk.

This extra payment is good policy unless your property is in such condition that you can be your own insurer. It would hardly pay a man who owned a thousand houses so distributed that it was hardly possible for one or two to burn at once to take out insurance. The extra payment he has to make over the expectation of loss would probably be more than any individual loss.

Of course computation in insurance is the theory of probability, but in this case the probabilities are not reckoned from a priori considerations, but are the results of long series of observations, more especially in life insurance than in insurance against fire. There is this strong difference between the two: In fire insurance, the expected loss will fall on only a few of the risks, while in life insurance the company must, in the end, pay in every case where the policy has been kept up. The uncertainty is in the time of payment, not as to whether there shall be any payment at all. Life insurance rates could be made much smaller if the insurance were run for only a limited time. A large part of the failures of so many assessment societies comes from a failure to recognize the distinction. The rates charged are much cheaper than the rates of the regular companies, and for a time furnish good term insurance, but unless the assessment society can keep down the average age of its policy holders, a thing which very few such companies are able to do, the cost must inevitably increase, and as years go on the assessment plan becomes more expensive than the regular. Generally such a society has to

quit business, and leave the surviving members without any insurance at all, and at ages too great to get any except at ruinous rates.

There is a very neat illustration of the working of the laws of probable deviation from the expected number in favor of the large company, which has to pay a large number of losses each year. Suppose the expected number of losses for a given year to be 100 and that observation has shown that most probable deviation from the expected number is 10. The company must therefore be ready to pay 110 losses, that is, it must have an additional 10% of its funds in such shape that it can be immediately turned into cash, and therefore invested at a lower rate of interest than could be obtained on more permanent investments. A company expecting 10 losses per year would have to provide for 13, but in this case 30% in addition to the expected amount must be kept ready. While a company expecting 1000 losses per year would have to provide for 1033, but this involves a little more than 3% additional to the cash funds.

The theory of probability is used successfully in all sorts of statistical investigations, from questions as to the credibility of spook stories and the existence of ghosts, to problems of natural selection and the theory of evolution.

If we are examining the question, say, of the height of men, or the number of rainy days per year, or the deaths from consumption, or relative numbers of males and females in different communities of a state, all questions where the individual result generally differs from the average—we find that there is a striking resemblance in the way in which the various individuals differ from the average. Small deviations are much more numerous than great, there are about as many on one side as the other. In fact the deviations are so regular that they can be plotted graphically in a curve, called the probability curve, which answers for all sorts of cases, and the curve showing the average number of rainy days per year with the deviations from it could be used in studying the chances in throwing dice.

In other words the questions of chance deviations from the average is a determinate one, and in case a mass of statistics of any kind shows greater discrepancies than theory requires, it is a fair inference that something other than mere chance is acting, and this principle is a fruitful one in the discovery of new laws.

Time and space are too limited to even enumerate the sub-

jects to which this kind of investigation is applied, but I can not forbear mentioning one. The address of a biologist at the Bristol meeting of the British A. A. A. S. which was entirely taken up with an argument for natural selection, was based on statistical data analyzed according to the laws of probability.

But I must spend the rest of the time on a portion of the subject, namely, the use of the theory in what may be called the sciences of measurement, Physics, Chemistry, and Astronomy, etc.

One of the most important applications of the Theory of Probability is the determination of the probable value of some quantity from a series of measurements, which are more or less discordant, and the determination of the probable amount of uncertainty in this value which is due to accidental errors of observation. When I speak of discordance in observations, I speak of the normal condition of affairs in almost every case where the highest accuracy is sought. Whenever a measurement consists of anything more than a mere enumeration, disagreements between individual results are to be expected if the best instruments are used and the most careful are made. I can count the money in my pocket or determine the state of my bank account with certainty and ease. The banker can state with absolute correctness the amount of money that is in the bank vaults at the end of any day. The census of any state or country can possibly be accurately made for any given time.

It is not such measurements that the theory of probability is applied in the way I am about to describe. Whenever we wish to determine accurately any length, or area, or angle, or volume, or weight, anything measurable beyond a mere counting, we can make use of probability, when the data of measurement are more numerous than theoretically necessary.

As I said before, complete agreement between different measures of the thing is not a sure sign of accuracy, but in most cases it is a sign of imperfection in the work. When I set a class of students to measuring the distance from the flagstaff in the campus to the lake shore, they may each independently report a distance of 2692 feet. But suppose another set of measurers report distances of 2692 feet. I will not have a great deal more confidence in the second series of measures than in the first. And when they attempt to state the distance in hundredths or thousandths of a foot, the discrepancy between the different measures will probably appear greater, but the accuracy will also be greater.

When my surveying class measures the angles of a polygon and their observations show that the sum of the angles has exactly its theoretical value, I do not congratulate them on their success but I feel there is more need of close watching than if they had reported a reasonable amount of discrepancy between theory and observation. When I sight a transit at any object, and continually get the same circle reading at different trials, I conclude that the optical power of the telescope is disproportionate to the graduation of the circle, and that the instrument is badly designed inasmuch as there is not the proper balance of accuracy between the parts.

Errors to which measurements are subject may be divided into two great classes, constant and accidental. Constant errors may arise in several ways: (1) From a lack of knowledge of the whole circumstance affecting the measurement. If I attempt to determine the latitude of a place by observations, of altitudes of stars without taking into account the refraction of the air my results will be discordant from a lack of attention to the theory of observation. (2) The instrument I use may not give exactly the altitude on account of wrong zero point or lack of centering or misplacement of marks of graduation, etc. (3) By one's own peculiar idiosyncracy in making an observation, may always make it too great or too small. That is what is called Personal Equation. Now all these errors must be taken into account and allowed for as far as possible. Observations must be taken with all possible variation of circumstances. Very frequently unknown and unsuspected laws have been brought to light by discordance between observations which have been corrected for all sources of error. The aberation of light and personal equation are good examples.

But after all of these things have been allowed for, it is found that there remains a lack of agreement between the different measurements, and now the theory of probability steps in to enable us to get the results.

First, where we have a number of determinations of some quantity all taken with the same care and all equally good a 'priori, it is assumed that the average, or arithmetic mean, is the most probable value of the quantity. Strictly speaking this is assumed although there are attempts at proof; but these all rely on assumptions that are no more obvious. The difference between this average and the separate results are termed residuals, and through an examination of their size and distribution

we can make an estimate of the accuracy of the result. It is very easy shown that the sum of all the residuals is zero when regard is taken of their sign. It may also be shown although with a little more intricate mathematics that the sum of the squares of the residuals formed by taking the differences between the average and the separate result is less than obtained by taking the difference between any other number and the separate results; and in the development of the theory, this sum of the squares of the residuals plays a much more important role than the residuals themselves, and hence the whole subject is frequently called the method of Least Squares.

Second, how can the accuracy of the result be measured? It can be measured by the mean of the errors, that is by the average residual taken without regard to sign—not much used. Or by the mean error, that is the number whose square is the average of the residuals. Or by the probable error, which is the error which lies midway in the series of observations, so that there are as many errors greater as there are less, or so that the chance of committing this error is just one-half. As small errors are more likely to occur than large ones this probable error is smaller than the mean of the errors, or the mean error.

If the number of observations is infinite, theory assumes that the average of all the results will be free from accidental error; but as our number of observations is limited, the average itself is uncertain, and this fact must be taken into account in getting the mean or probable errors of the single observation. Then the theory shows that the errors of the average result are inversely proportional to the square roots of the numbers of observations and we have the formulas.

But the original observations are always uncertain to a considerable degree. The object is faint and the determination of its position depends on the position of neighboring stars, the state of the atmosphere, and a good many other things, all affecting the measurement. The elements computed are therefore in like manner uncertain.

Obviously the method of averaging can not be used to any great extent. The object is continually in motion, and where the interval between the observations is large the uncertainty of the approximate value of the elements affects the position so greatly that averaging would lead to incorrect results.

When approximate values are known we may take the relation between the observations and the corrections to be determined

to the approximate values by means of equations of the first degree, each observation giving a single equation all the corrections as unknown quantities with coefficients varying from one equation to another.

In order to get a definite solution the number of equations should be just the same as that of the unknown quantities, that is, the whole number, perhaps 100 or more, must be reduced to six in such a way that the resulting values of the unknown quantities are the most probable.

This is affected in the following way, calling the unknown quantities $x$, $y$, $z$, etc. We must multiply each equation of condition, as it is called, by the coefficient of $x$ of that equation, and take the sum of the products. This gives us the normal equation in $x$. A similar process gives us an equation for each of the other unknowns; and thus we have reduced the number to that of the unknown quantities. The solution of these normals will give the most probable values of the unknowns.

Now to find the probable errors of the various quantities, the values thus found are substituted in the various equations of condition, and the discrepancies shown are treated in about the same manner as the residuals already described. And the final probable error of each unknown is determined from these and the coefficients of the normal equation.

There is scarcely a measurement problem in Physics, Chemistry, or Astronomy in which observations more numerous than the number of unknown quantities are not taken, and this method of least squares to treat such cases is coming into almost universal application. When a new determination appears of any number connected with these sciences, the question at once arises; how accurate is the work? What is the probable error? And unless this is stated in some way, the result is open to suspicion.

From this brief paper, I hope to show that from a large uncertainty in an individual case we may often arrive at a reasonably definite conclusion as to the class of objects to which the individual belongs, that we may protect ourselves against uncertainty in many cases, that we may discover new laws or form an estimate of the evidence for old ones—in short, that which we call blind chance has after all discoverable uniformity in its operations.

## THE PROJECT PLAN IN THE TEACHING OF PHYSICS.

By J. P. Drake,

*Normal School, Emporia, Kansas.*

If there is anything of value in the Project method of teaching, we, as teachers of Physics, should make use of it. Physics as now taught, is too often dry, disconnected and uninteresting. In this scientific age, there are many subjects in Physics which will excite and hold the interest of our young people, if they are properly introduced and if the subjects are presented in the right manner.

It has well been said that under the project plan the student works because of an "inward urge" rather than from an outward compulsion. Those of use who know young people readily understand that there is a vast difference in these two conditions, not only in the amount of work which may be accomplished in a given time, but also in the ease with which that work is accomplished. I have in mind a boy who will work hard and over-time if he has this "inward urge" but will only mark time, if he is working simply from outward compulsion. This boy is no exception to the rule.

I believe that the subject of Physics lends itself, as well as does any subject, to the Project—Problem Method. If the teachers of Physics will think out and work out with their classes certain large projects and report results to a central committee, in a year or two we would have an abundance of interesting and valuable material. The following projects may illustrate my meaning: How may we heat and ventilate our homes? How may we light our homes and equip them with electrical appliances? Each of the above projects will furnish material for a month or more. A semester's work in electricity may well be woven into a project on Wireless Telegraphy. If there is any phase of electricity that does not connect up easily with this subject, I do not know what it is.

I have been asked by your chairman to speak of a project which is being worked out at the Roosevelt High School, the Normal Training High School of the Kansas State Normal School. In nearly every department of our school the Project Method is being tried out. When planning the work in Physics, it was suggested that if we had a project large enough and one of common interest, the work of the entire year might well be arranged about this one project.

We have in Kansas enough automobiles so that if all of the people of the state should decide to go to church some Sunday morning, they could all ride in autos and none would make a second trip. It was finally decided to sound the class on the subject of the Gasoline Automobile. This seemed to be a project which interested all and they finally decided to start in and work so long as the interest of the class was satisfactory.

It is the aim of the instructor in charge to teach as much Physics as formerly and many of the same subjects and experiments, but to connect it up to one main Project and study a subject or perform an experiment at the "Psychological Moment" when they really want to know about the thing at hand for a definite purpose.

When studying the frame, a study of strength and stiffness of materials may be studied; when speaking of the compression and expansion of the gas in the cylinder, the laws of gasses may be experimented with; when studying the spark and sparking systems, the induction coils, batteries, magnetos, etc., may form the basis of class and laboratory work for a time. The teacher will have but little difficulty in connecting up the big topics in physics to this large project.

I was interested recently to see how many important topics I could think of off hand which are related to this project. Following is a list which could easily be enlarged: Laws of motion, forces, energy, power, transformation of energy, gravitation, centrifugal force, accelerated motion, machines, transmission of pressure, pumps, barometric pressure, Boyle's law, siphon, density and specific gravity, temperature, thermometers, sources of heat, heat due to compression, friction, conduction, convection, radiation, heat due to chemical action, ventilation, expansion, law of Charles, liquefaction, solidification, laws of fusion, freezing mixtures, vaporization, ebullition, distillation, specific heat, B. t. us. in gasoline, latent heats, steam engine mufflers, horns, vibrations, electric lights in series, and parallel, gas lights, mirrors, lenses, shadows, dry cells, storage batteries, coils, magnetos, generators, frictional electricity, magnets, ammeters, voltmeters, resistances, electric motors.

Some one may ask how the subject of the telephone could be related to this topic? This objection is easily answered when you run out of gasoline 10 miles from town, and want to telephone for help.

The class has worked at this project for ten weeks using the state text as a reference book, along with others, and the interest has been keen all of the time. Prof. W. A. VanVoris has charge of this work and is working out his outline as he goes along. If the interest lags in the spring, then other smaller projects will be substituted.

The plan is working well at present with a mixed class, half boys and half girls.

If this project works out as well as it seems to be working, I would recommend that this be used for the first semester and since the personnel of the class is likely to change some at that time, I would suggest for the second semester three shorter projects, one relating to methods of communication with and without wires, one about music and musical instruments, and the other about the eye and optical instruments such as the microscope, telescopes, lanterns, etc.

The exact statements of the projects and the best approach must be worked out by physics teachers.

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## TROPICS CAN FEED JAPAN AND CHINA.

Land enough to supply all the food wants of Japan, China, the Philippines, and other countries in eastern Asia exists in the tropical islands of the far east, Dean E. D. Merrill of the College of Agriculture of the University of California recently told members of the Pacific division of the American Association for the Advancement of Science.

Borneo, Sumatra, and New Guinea, each of them larger than Japan proper, have a combined population of less than 9,000,000 as against 70,000,000 persons in Japan. Java supports a population half as large as that of Japan on a territory only about 30 per cent. as large. The future food supply of the East will have to come largely from these great areas of untilled land in the tropics, Dr. Merrill said.

Even in China there is room for a considerable expansion in food production, if rinderpest, a cattle disease which makes cattle raising unprofitable there, could be eradicated, the speaker said. Large areas of China are typical grazing land, and while the country imported large quantities of rice, it exported a great many food specialties, particularly eggs.

"Unless one has traveled in the Malay archipelego, one's ideas as to the size of the region are apt to be rather hazy," Dr. Merrill said. "If a map of the archipelego be drawn to the same scale and placed over a map of the United States, the northern end of Sumatra would appear on the coast of northern California, Oregon or Washington, while a large part of the great island of New Guinea would extend into the Atlantic ocean.

"To these vast undeveloped areas may be added large regions in the Malay peninsula and the Philippines. It would seem desirable to develop some of these regions as basic food producing areas, and this development may be forced, in the not distant future, by changing economic conditions. To develop these countries, however, labor must be available in the form of largely increased population; yet there is always the personal element to be considered in that Malay peoples are in no sense colonizers."—*[Science Service.*

## HISTORIES OF MATHEMATICS BY FLORIAN CAJORI AND D. E. SMITH.

By G. A. Miller,

*University of Illinois, Urbana, Ill.*

It is well known that the second edition of Cajori's *History of Mathematics*, which appeared in 1919, was so extensively revised and enlarged that it may be regarded as practically a new work. More recently (1923), D. E. Smith published the first volume of his *History of Mathematics*, and the second volume is expected to appear soon. Fortunately, these two recent American works supplement each other to a large degree, since the former deals much more extensively with recent developments than the latter, which will probably appeal more strongly to a younger class of mathematical students by means of its numerous pictures and other illustrations as well as by its style and subject matter.

In earlier numbers of this periodical (volume 19, page 830; volume 20, page 300; volume 23, page 138), the present writer suggested certain incomplete marginal notes relating to the former of these works in the hope that teachers might find them helpful while using the work as a textbook. He also hoped that other readers might find some of these notes interesting and useful. Encouraged by the remarks of several friends who had found these notes actually helpful, and desiring to act impartially as regards these two popular recent American contributions towards making it easier to secure some insight into the history of the development of the vast subject of mathematics, he gives below a similar list relating to the latter. He expects to extend this list after Volume 2 has appeared, a sufficient time to be carefully read by him.

Page VIII. The closing sentence states that the first page reference after a proper name in the Index relates to the biography, if one is given, and that the others "are arranged approximately in order of importance." On looking through this Index one finds no evidence of any effort to comply with this unusual and difficult mode of arranging page references to authors. The only proper name after which the page references following the first are not arranged in the order of the ascending magnitudes of the page numbers is that of *Libri*, and in this case the actual arrangement is due to an error since the page reference relating to his biography does not appear first. As it is so easy to verify that this promise near the beginning of the work is not complied with one naturally feels less inclined to

expect that the author considered all of his statements very carefully.

Page XIV. Under "Cantor." Since Cantor's *Vorlesungen über Geschichte der Mathematik* is now known to contain thousands of errors, it seems questionable whether it should still be called "the standard general history of mathematics." In fact, it seems doubtful whether any work which closes with the beginning of the nineteenth century can still be properly called a "general history" of our subject in view of the fact that so much of our modern mathematics was developed later and its history is at least as important to the modern student as the history of older advances in this field.

Page XV. The date of the 2d edition of Tropfke's work should be 1921—instead of 1922. The first two of the seven volumes are dated 1921. It is interesting to note that our author called this "the best history of elementary mathematics" long before it was completed. Volume 6 appeared in 1924, while volumes 4 and 5 bear the date 1923.

Page 8, line 26. Since we do not know what the primitive radix was it seems questionable to state positively that it was not ten.

Page 12, line 2. It is here stated *definitely* that "we have one relic of the scale twelve in our system of counting, for we do not begin the usual form of the decimal naming of numbers when we reach ten, but we say 'eleven, twelve' instead of 'oneteen, twoteen.'" This quotation bears out the fear expressed above that our author did not consider some of his statements with much care, for he himself had noted near the bottom of page 10 that eleven may mean "one over ten" and that twelve may mean "two over ten." It is not implied here that a work which involves many lax statements may not be very useful, but the reader, especially the young reader, should be informed as regards this important feature. For instance, page 9 can be read more profitably if this feature is kept in mind. This also applies to many statements relating to mathematical archeology.

Page 14, line 10. It is here stated that the Hindus developed a numeral system which is "the most extensive to be found among any ancient people." On page 5 of volume 1 (1921), Tropfke's *Geschichte der Elementar-Mathematik*, it is noted that also in China $10^{53}$ was used as a kind of base of a number system dealing with very large numbers.

Page 31, line 12. It seems questionable whether stories about

mathematicians in a serious history of mathematics should include a tradition relating to "a wrist like a swivel, on which his hand could turn completely round." The trouble about such stories is that they take space which is much needed for true stories.

Page 37, line 7. Instead of "In no part," read in no other part.

Page 41. The probable reason given here for the selection of 60 by the Babylonians is not now commonly accepted by writers on the history of our subject.

Page 42, line 13. It is difficult to see why the old Egyptian calendar, in which the year was supposed to have 365 days, is here called *better* than the one used in Europe for many centuries, in which the year was supposed to be one-fourth of a day longer, even if the older arrangement, as regards the days in a month, is assumed to be better. Europe would not then have tolerated a 365-day year for so many centuries. The statement that "our own calendar may be said to be merely a poor adaptation of this ancient Egyptian one," is evidently an exaggeration, since we clearly would not get along with a 365-day year.

Page 59, line 6. The statement that "Egypt knew the fact relating to the square on the hypotenuse of a right-angled triangle long before Pythagoras" may be compared with the following: "Nothing in Egyptian mathematics suggests that the Egyptians were acquainted even with the special cases of Pythagoras' theorem concerning the squares on the sides of a right-angled triangle." Cf *American Mathematical Monthly*, volume 31, 1924, page 250. The statement of the book under consideration is, however, found in many other places.

Page 63, line 5. The statement that the Greeks knew such identities as $(a+b)\ (a-b)=a^2-b^2$ should be compared with Tropfke's *Geschichte der Elementar-Mathematik*, volume 2, 1921, page 96, where it is noted as a singular fact that this particular identity does not appear explicitly in Euclid's *Elements*, and that in a clearly expressed form it appears for the first time in a work by Nemorarius, who died about 1237.

Page 72, line 24. The remarkable statement that Pythagoras "established a brotherhood that has ever since served as a model for all the secret societies in Europe and America" should be compared with the following: "The supposed secrecy may even have been invented to explain the absence of documents." T. L. Heath, *History of Greek Mathematics*, volume 1, 1921, page 66.

Page 89, line 4. In speaking about Plato our author states

here that "in the field of mathematics, his great contribution was to the underlying principles of the science, including the method of analysis." This may be compared with the following: "It may therefore well be that the idea that Plato discovered the method of analysis is due to a misapprehension." T. L. Heath, *History of Greek Mathematics*, volume 1, 1921, page 291.

Page 91, line 12. The subject of spherics is not the same as that of mathematical astronomy, although the sphere was largely studied by the early Greeks for astronomical purposes. According to Tropfke's *Geschichte der Elementar-Mathematik*, volume 5, 1923, page 102, the pure mathematics of the sphere was probably in the fore ground in the work of Eudoxus of Cnidus.

Page 94, line 32. It is here stated that Pappus was a mathematician of the fourth century while on page 136, it is stated that he probably flourished in the third century. See also page 95, line 7.

Page 110. It is not now generally believed that the results of Eratosthenes were as nearly accurate as is here stated. Cf. *Encyclopédie des Sciences Mathématiques*, tome 6, volume 1, page 6.

Page 114, line 2. We should not now write equations in this form since $b^2$ is meaningless in this form.

Page 116, line 17. The Greek myriad, or the Japanese yorozu (page 144), was evidently too large for a primary base. It was not "the base of all great systems of numeration in the East as well as in Europe for many centuries" as here stated. In particular, the much larger base $10^{53}$ was used in China and in India.

Page 119, line 12. This statement is contradicted by Tropfke, *Geschichte der Elementar-Mathematik*, volume 1, page 40.

Page 126, line 20. The statement "that the general quadratic as we know it today, was thus fully mastered by the Greek mathematicians" is clearly an exaggeration, in view of the fact that the Greeks could not solve such equations when the roots are either negative or imaginary. Cf. This journal, volume 24, page 509.

Page 146, line 20. Instead of "any," read any other. The statements found in the last paragraph of this page are in disaccord with the *Encyclopaedia Britannica*, 11th edition, volume 2, page 809.

Page 148, line 6. Instead of "West," read East.

Page 175, line 16. According to Tropfke's *Geschichte der Elementar-Mathematik*, volume 5, page 24, the concepts of tangent and co-tangent were used earlier.

Page 179, line 9. The works of Boethius did not treat the theory of numbers and demonstrative geometry in the modern sense of these terms. Demonstrations were usually avoided by Boethius and his followers, and the more advanced Greek theorems relating to numbers were also avoided by them.

Page 226. In regard to foot-note number 3, see the *Mathematical Gazette*, volume 12 (1924), page 129.

Page 246, line 1. Instead of "three," read four.

Page 260, line 8. Since the work of Nasir Eddin has become known it is not customary to speak of this work by Regiomontanus as "the first work that may be said to have been devoted solely to trigonometry." Such statements were common before the work of Nasir Eddin became known in Europe.

Page 261, line 20. In regard to the statement that nothing is known about Chuquet, except his statement that he was a "bachelor of medicine and that he wrote his work at Lyons" it may be noted that earlier in the same paragraph he is called "a native of Paris."

Page 277, line 3. From the bottom, in place of $a+0=0$, read $a+0=a$.

Page 281, line 26. The "relations" referred to here are not actually stated.

Page 283, line 23. It is here stated that the rule

$$\left(\frac{a+b}{2}\right)^2 - \left(\frac{a-b}{2}\right)^2 = ab$$

is probably due to the Hindus while on page 92, volume 2, of *Tropfke, Geschichte der Elementar-Mathematik*, a similar rule is obtained from Euclid's *Elements*.

Page 324, line 26. Instead of "three countries," read two countries. The statement in line 20, that "the first trace of trigonometry in any work printed in England" appears in a work by Blundville published in 1594, seems to be incorrect, since spherical trigonometry was used already in the books by Thomas Digges, according to Ball's *History of Mathematics at Cambridge*, 1889, page 21.

Page 331, line 15. The trigonometry by Pitiscus cannot be regarded as *satisfactory* from the modern point of view. In particular, it does not give the ratio definitions of the trigonometric functions. In the 1600 edition, Pitiscus declared that angles which exceed 90° do not have tangents or secants. The general curves representing the six trigonometric functions were not known until much later.

Page 347, line 26. As Regiomontanus died when Copernicus was only a little more than three years old, the latter did not go "to Rome for the purpose of continuing his work in astronomy under the guidance of the great Regionmontanus." This error is found in very many other places. Cf. *Science*, volume 60 (1924), page 82.

Page 348, line 2. It is evidently an exaggeration to say that "Copernicus opened millions of worlds." He did not invent the telescope. On page 108, we are told that Aristarchus anticipated him by seventeen centuries.

Page 359, last line. Instead of "any," read any other.

Page 360. About the middle of this page the words "spirit" and "times" should begin with small letters.

Page 377, line 6. The dates after the name of Van Shooten belong after that of Fermat.

Page 391, fifth footnote. Here the fact that the year in England then began on March 25 is explicitly recognized by the dates 1560/61 and 1630/31. This is, however, not done in many other cases. In particular, it is not done in the case of Newton, page 398.

Page 400, line 20. Newton did not consider the expansion of $(a+b)^n$ for *all* values of $n$. See Miller, *Historical Introduction to Mathematical Literature*, 1916, page 209.

Page 404, line 9. This exaggeration as regards the work of Newton should not be quoted approvingly in a history.

Page 406, line 4. Instead of "the focus," read a focus.

Page 418, line 5. The statement "there is no longer any doubt that Leibniz developed his calculus quite independently" may be compared with the *Encyclopédie des Sciences Mathématiques*, tome 2, volume 1, page 247, where such doubt is expressed, in fact the statements which follow the one just quoted seem to indicate doubt on the part of the author of the work under consideration.

Page 423, line 5. The statement that Snell discovered the properties of the polar triangle is in disaccord with the well known fact that these properties were discovered by Vieta. Cf. Tropfke, *Geschichte der Elementar-Mathematik*, volume 5 (1923), page 125. The modifying clause, "as others had done," in line 15, on this page is questionable. It is true that Peter Rothe had stated as early as 1608 that an equation of degree $N$ may have $N$ roots, but Girard seems to have been the first to emphasize the introduction of imaginary roots, when necessary

so that the equation of degree $N$ has actually *always* $N$ roots.

Page 428, line 7. The statement that Jacques Bernoulli wrote the first book devoted to the theory of probability may be compared with the fact that Huygens had at an earlier date (1657) prepared a treatise on this subject. Cf. Cajori's, *History of Mathematics*, 1919, page 171.

Page 430, beginning of last paragraph. It is true that Jean Bernoulli claimed that the use of the term "integral" was due to him, but it is not generally believed that he told the truth in this case. Cf. Cantor, *Vorlesungen über Geschichte der Mathematik*, volume 3, page 219.

Page 440, line 7. Too much credit seems to be given here to Seki, in regard to the invention of determinants. It is interesting to note that Seki is not mentioned in the brief history of determinants contained in Tropfke's *Geschichte der Elementar-Mathematik*, volume 2 (1921), page 36. The claims for Seki seem to be based on very meager contributions along this line.

Page 446, line 14. The sentence, "with the 18th century, the King of France, no longer stands out as the sole patron of science," is misleading since many royal patrons of science outside of France lived earlier in Europe and elsewhere. The histories of some of the early universities give evidence of this fact, see also Alfonso X, page 228.

Page 449, line 15. According to the *Bulletin of the American Mathematical Society*, volume 29 (1923), page 184, James Stirling was not expelled from Oxford in 1715, as is stated here.

Page 451, line 6. Instead of "73d day," read 72d day.

Page 459, line 4, from bottom. The date 1843 does not agree with the one given in the *Royal Society Index* and elsewhere.

Page 462, line 24. In speaking about De Morgan, it is stated here that his articles on the history of mathematics "are not only eccentric but unreliable." Hence it may be somewhat amusing to refer to page 469 of volume 22 of the *Bulletin of the American Mathematical Society*, where it is stated as a compliment to D. E. Smith, that "the similarity of his literacy and public activity to De Morgan's is striking."

Page 469, line 25. It is somewhat misleading to speak of Sir James Ivory, as "with mathematics as an avocation" in view of the fact that he taught mathematics for about fifteen years and was pensioned during the latter part of his life on account of poor health. While he was in business during the early part of his life he devoted much of his time to the study of mathematics.

His success along this line is established by the fact that he is one of the six American or English Mathematicians who were elected corresponding members of the Paris Academy of Sciences, since 1816, according to the *American Mathematical Monthly*, volume 27 (1920), page 384. Even Cayley did not receive this significant honor, although he richly deserved it.

Page 475, first footnote. According to Tropfke, *Geschichte der Elementar-Mathematik*, volume 3 (1922), page 98, J. P. de Gua died in 1785.

Page 480, line 15. J. H. Lambert was neither a French writer nor a *minor* writer of the middle of the 18th century.

Page 485, line 6. Such an accusation against Paris, as "The Prussia of that day wished to be scientific; the Paris of that day merely wished to be thought so," can fortunately not be proved to be correct.

Page 486, line 29. According to the best authorities, Laplace had been in office much less than "six months" when he was dismissed by Napoleon. As considerable progress has been made in the theory of celestial mechanics since the time of Laplace, he should not now be regarded to "stand unrivaled," as is done in line 8 of the following page. In particular, Le Verrier and Newcomb are later authors of profound investigations, relating to the solar system.

Page 499, line 7. Instead of "no one," read no one else.

Page 500, line 7. Argand wrote on the graphic representation of $a+bi$ and not on the graphic representation of the number $i$, or $\sqrt{-1}$, only.

Page 505, line 8. Many others began teaching before they were twenty-four.

Page 510, line 16. G. Cantor began to publish on the theory of assemblages before 1879.

Page 515, line 4. The value of $\log(+1)\cdot\log(-1)$ is not $\pi^2$ as here stated. Its smallest positive value is $2\pi^2$. Cf. *Encyclopédie des Sciences Mathématiques*, tome 1, volume 1, page 355.

Page 522, line 6. The sentence "In his lifetime there appeared about nine hundred important memoirs from his hand," may be compared with Eneström's *Verzeichnis der Schriften Leonard Eulers*, 1910, where 562 publications to the end of the year 1783, in which Euler died, are noted. On the same page the value of Euler's constant is incorrectly stated, and the date of Hankel's *Entwickelung der Mathematik* is not quite correct.

Page 530, near bottom. The name of Mittag-Leffler appears here in the text but not in the Index of this volume.

Page 542, line 3. The statement "naturally, however, the best histories of mathematics have never been written by the best mathematicians," seems somewhat out of place here, since Kästner was not one of the best mathematicians. He is said to have been regarded as a poet among mathematicians and as a mathematician among poets. In the preface of the first volume of the *Histoire des Mathématiques* by Montucla, the very significant fact is stated that the first element in preparing for writing this history was to secure a sufficiently profound knowledge of all the parts of mathematics, of which the system is so vast. The emphasis on the history and the method of teaching without understanding the subject is pernicious; a profound insight into the subject itself should always receive first consideration.

Page 543, line 26. In view of the appearance in 1914, of a second edition of G. Loria's *Le Scienze Esatte nell' Antica Grecia*, it is questionable whether Allman's work of 1889 should be called "a work unsurpassed in its line until the appearance of Sir Thomas Heath's history of 1921.

Page 571. The Index of 26 pages does not include any of the following names of influential writers on elementary mathematics: Enriques, Hadamard, Hilbert, Hobson, Klein, Moore, Peano, Perry, Russell. The names after which there appear more than four page references are as follows: Euclid (18), Tannery (17) Heath (9), Karpinski (9), D. E. Smith (8), Boncompagni (7), Ptolemy (7), Steinschneider (7), Apollonius (6), Ball (6), Bosmans (6), Cajori (6), De Morgan (6), Günther (6), Heiberg (6), Loria (6), M. Cantor (5), Eneström (5), Favaro (5), Suter (5), Woepcke (5). Among those whose names are followed by one page reference are the following: Abel, Cauchy, Cayley, Cremona, Descartes, Euler, Galois, Gauss, Hamilton, Kronecker, Lagrange, Leibniz, Lie, Monge, Newton, Poincaré, Steiner, Vieta and Weierstrass.

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**TINY PLANT PARASITES STRIP SYCAMORE TREES.**

Sycamore in Illinois, Ohio, Pennsylvania, New Jersey, West Virginia, and Arkansas are being completely stripped of leaves by a heavy infection of sycamore blight, a fungus disease known as Gnominia veneta, according to reports received by the U. S. Department of Agriculture. In Ohio the same plant parasite which is damaging the sycamore has also attacked the white oaks. Many valuable trees will be severely damaged if not completely killed by the epidemic. The cool, wet spring is thought to have favored the growth and spread of this sycamore blight.

## GEOMETRY, A LABORATORY SCIENCE.

By Joseph A. Nyberg,

*Hyde Park High School, Chicago.*

AN EXPLANATION BY THE EDITOR.

**The presentation of an idea through the printed page has some advantages over the presentation before an audience at a meeting of teachers. The writer may always revise his work so as to express his idea in its best phraseology, and the reader can judge the ideas more impartially. On the other hand, at a meeting of teachers the discussion which follows and the criticism of the idea by various members enables the listener to hear arguments against as well as for the subject.**

**In this instance the editor has decided to try a plan that aims to give the reader the advantage of both methods. The critics have been asked to discuss the article in the same manner in which they might comment on it if the ideas were being presented at a meeting of teachers. The article below is thus discussed by F. M. Sutton, Principle Fresno, Calfornia Technical School and John V. Pyle, Homious Technical School, Chicago.**

**In this particular instance the article is itself a comment on a previous article.**

The following article is a discussion of the paper under the same title by Wm. A. Austin, High School, Fresno, Cal., which appeared in School Science and Mathematics, January 1924, pages 58-71, and two earlier papers, November 1919 and October 1921. Interest in this subject is increasing. At the meeting of the National Council in February at the LaSalle Hotel, Chicago, Mr. Charles Stone of the University High School also presented a paper on the Laboratory Method in the Classroom.

The essentials of the laboratory method as stated by Mr. Austin (page 622, Oct. 1921) are that the pupil must take the following steps in arriving at a general truth:

1. Make constructions according to specific directions;
2. Take measurements and perform computations;
3. State the conditions of construction and the apparent conclusion;
4. Give the usual formal proof to establish the truth in general; and
5. State the general truth in the form of a proposition.

How closely we may come to attaining these essentials in an ordinary classroom and without any special equipment can best be seen by explaining first how geometry is taught at the Hyde Park High School.

During the first two weeks of the course when the pupil is learning the definitions of such words as *perpendicular, bisector of an angle, altitude,* etc., the pupil is also taught how to construct these lines with a ruler and compass. His equipment is an ordinary compass, costing about 25 or 35 cents, and a ruler; a foot-rule cut in half will do as the pupil seldom needs to draw a line longer than six inches. Sooner or later the pupil

manages to secure a celluloid or tin ruler like those distributed for advertising purposes by many commercial firms. This can easily be kept in the textbook and will not break the binding of the book. The pupil brings his ruler and compass to class each day just as he brings his book, pencil, and paper. Then as stated above, on the same day that the pupil learns the definition of perpendicular he is also taught how to construct one. The teacher some day defines *median*, and two minutes later as many of the class as can be accommodated are at the blackboard constructing medians (using a piece of string tied to chalk as a compass) and the other pupils are doing the same at their seat. No proofs are given that the construction is correct, the pupils being told that this will be learned later.

From the first day of the year the pupil is thus required to construct the figure for every theorem and exercise discussed during the course. When he is about to prove that a quadrilateral is a parallelogram if a pair of opposite sides are equal and parallel he must construct the lines equal and parallel.

Besides the advantages which Mr. Austin has pointed out we might mention several others. First, we have here an additional motivation of the beginnings of geometry; the class is told that the object of the first month's work is to prove that these constructions are correct, and extra credit (toward a higher grade) is the reward of the first pupil who succeeds in proving the correctness of a construction. Another advantage lies in the neat orderly work which this method encourages; a good figure is conducive to a legible handwriting and an attractive arrangement of the proof. A third advantage shows itself when the class reaches the problems on loci and the so-called construction problems wherein, for example, the pupil is to construct a triangle given two sides and the altitude to the third side. By that time the pupil has become so familiar with his ruler and compass that such exercises offer no difficulty worthy of mention. A fourth advantage is that many errors which arise when the pupil is allowed to make free-hand sketches of the figures are less frequent and soon disappear when the figures are constructed. If, for example, the pupil says in some proof that AB = CD merely because AB looks equal to CD in the picture in his book, the teacher has merely to ask "Did you make them equal in your construction?" and the pupil sees his error. There is still a fifth advantage which is mentioned last because it is the greatest of all. It is obvious to a teacher that

any proof not only *uses* the information given in the hypothesis but also that the proof *begins* with these known facts and works toward the conclusion. This important fact becomes clear to the pupil when he is required to construct his figure because the hypothesis is the only information which can tell the pupil how to construct his figure. When the pupil says "I didn't know what to write next in my proof" the teacher has merely to ask "What did you do next in your construction?" The construction is the best clew to the proof, particularly during the first months.

The second point in Mr. Austin's method is that the pupil must "take certain measurements and perform computations." The object of such computations is obviously not to review arithmetic (although we might well use it to practise the multiplication of approximate numbers—see page 627, October 1921) but to impress on the pupil the law or principle under discussion. Such measurements also increase the chance of the pupil's remembering the theorem later. We, however, do not spend more than three or four minutes on such measurements. After bisecting an angle we may measure the two halves with a protractor or, if discussing the theorem about two intersecting chords, we may measure the four segments and find certain products. These measurements are performed at the time when the particular theorem is assigned for the next day's homework and are in fact intended only to clarify the meaning of the theorem so that the pupil can later attack his homework in a better frame of mind. The measurements are not discussed the next day and are not recorded. Besides helping to clarify the theorem, the measurements, being inexact, furnish a motive for proving the theorem by a logical use of our previously accumulated knowledge.

The third point is: State the conditions of construction and the apparent conclusion. Herein lies the biggest difference between Mr. Austin's method and ours. We do not expect the pupil to discover the conclusion as the text tells what is to be proved. Hence our method is not a true laboratory method and could not be made so without using a specially prepared text. If, however, this is the essential item in a laboratory method then even physics and chemistry are not taught by a laboratory method in high schools for in both subjects the pupil is told in his text what the various laws and reactions are. Moreover we feel that there are very few places where the pupil

could discover the proper conclusions without making more measurements than time will permit. Would the pupil, for example, ever discover that the altitude to the hypotenuse of a right triangle is the mean proportional between the segments of the hypotenuse?

The fourth point is: Give the usual formal proof to establish the truth in general. On page 70 (January ,1924) an illustration of two of these proofs is shown, and here a weakness of the "plate" method is evident. After showing the experimental work the proof is much abbreviated because there is room on the paper only for the most important steps. Although it is obviously impossible and even undesirable to present all the steps of a proof, nevertheless we think the proofs shown on page 70 encourage considerable loose thinking. In place of the first proof on plate XXXIII we would expect the following:

(Steps 2, 3, 5, 7, 10 and 12 would be omitted in a review or after the pupil has used them for more than a month.)

| | | |
|---|---|---|
| 1. | Draw chord AC. | |
| 2. | $x$ is an exterior $\angle$ of $\triangle$ APC. | |
| 3. | $x = y + p$. | An exterior $\angle$ of a $\triangle$ equals the sum of the two remote interior $\angle$S. |
| 4. | $p = x - y$ | Transposing $y$, and rewriting. |
| 5. | $x$ is an inscribed $\angle$. | |
| 6. | $x = \frac{1}{2}$ arc AD. | An inscribed $\angle$ is measured by half its arc. |
| 7. | $\angle 2$ is a central $\angle$. | |
| 8. | $\angle 2$ = arc AD. | A central $\angle$ is measured by its arc. |
| 9. | $x = \frac{1}{2}\angle 2$. | Substituting step 8 in step 6. |
| 10. | $y$ is formed by a tangent AP, and a chord, AC. | |
| 11. | $y = \frac{1}{2}$ arc AC. | An $\angle$ formed by a tangent and a chord is measured by half its arc. |
| 12. | $\angle 1$ is a central $\angle$. | |
| 13. | $\angle 1$ = arc AC. | See step 8. |
| 14. | $y = \frac{1}{2}\angle 1$. | Substituting step 13 in step 11. |
| 15. | $p = \frac{1}{2}\angle 2 - \frac{1}{2}\angle 1$. | Substituting steps 14, 9 in step 4. |
| 16. | $= \frac{1}{2}(\angle 2 - \angle 1)$. | Factoring in step 15. |
| 17. | $= \frac{1}{2}$(arc DA—arc AC) | Substituting steps 8, 13 in step 16. |

(The proof could be much shortened by omitting any reference to $\angle 1$ and $\angle 2$.)

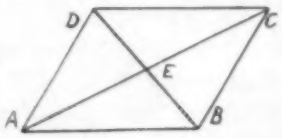
We do not mean to imply that all exercises are solved with so much detail. To derive a certain proportion in the classroom, for example, we may have one pupil draw the figure at the board, ask another pupil to state which triangles are similar, and ask others to prove two pairs of angles equal. From observations taken with a watch in front of us we know that this requires only three or four minutes and a dozen or more such exercises may be discussed in this manner each week in class. In the written homework, however, the pupil must present a complete proof.

The fifth point is: State the general truth in the form of a proposition. This is very good practise and is in agreement with the newer tendencies in algebra; namely, the use of exercises wherein the pupil is asked to translate an algebraic expression into words as, for example: State in English the meaning of such expressions as $2a+3b$ or $5x+2=3(x+2)$. As a preparation for a certain theorem in the next day's assignment we may write on the board

$$\text{If } \frac{a}{b} = \frac{c}{d} \text{ then } \frac{a+b}{b} = \frac{c+d}{d}$$

and ask the pupil to translate this relation into words. Or, with the figure below we may write on the board

If ABCD is a parallelogram, then AE = EC, DE = EB.

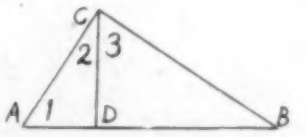



and ask the pupil to state what principle is illustrated. Such exercises are particularly valuable in a review where the object is to find out how strong in the pupil's mind are the associations between general principles and their applications. Exercises of this type have also been used by the writer at the end of the first semester to determine the pupil's fitness to continue in geometry. Thus we use Mr. Austin's step five in our classroom technique but use it for different purposes.

The object of this article was to show how closely we may come to a laboratory method in an ordinary classroom. The teacher who wishes to try these methods with any standard text needs to be warned of certain features.

First, the exercises must be carefully chosen particularly at the beginning of the work, some of the fundamental theorems must be assumed and some of the proofs restated. Consider the following exercise:

$\angle ACB$ is a right angle and $\angle 1$ is the complement of $\angle 2$. Prove $\angle 1 = \angle 3$.



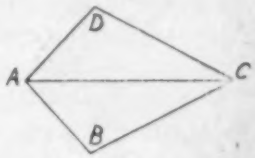

This exercise occurs immediately after the statement "Complements of the same angle are equal" and is to be proved accordingly. But in constructing the figure, the pupil draws $\angle ACD$, draws $CB \perp CA$, selects a point A and at that point he wishes to construct an angle which shall be the complement of $\angle 2$. He can do this only by copying $\angle 3$. Hence there is nothing to prove because $\angle 1 = \angle 3$ by his construction. Such

an exercise must be omitted or one like the following substituted for it:

Given $\angle BAC$. At A construct $AD \perp AB$ and $AE \perp AC$. By our construction $\angle CAD$ is the complement of $\angle BAC$, and $\angle EAB$ is also a complement of $\angle BAC$. Prove $\angle CAD = \angle EAB$.

Again an exercise like

In a quadrilateral ABCD, AC bisects $\angle A$ and also bisects $\angle C$. Prove $\triangle ABC \cong \triangle ACD$.




must be changed to

In the quadrilateral ABCD, AC bisects $\angle A$, and $\angle ACB = \angle ACD$. Prove $\triangle ABC \cong \triangle ACD$.

The pupil can now perform the construction by drawing any $\angle BAD$, bisecting it, selecting a point C on the bisector, drawing any line DC, and then copying $\angle DCA$ below the line AC. In certain theorems such as

A tangent to a circle is perpendicular to the radius drawn to the point of contact

the construction is impossible until after the theorem has been proved because the conclusion tells how to perform the construction. But such theorems are very few and are easily recognized.

A second feature deals with the assigning of the next day's homework. We assume that no teacher assigns homework by merely stating "To-morrow's homework is Theorem 18 and exercises 1, 2, 3" but also discusses what the theorem means, for what it can be used, the general method of proof, etc. In addition to these items there should also be an explanation in class, preferably by a pupil, of the construction. Otherwise Johnny will come to class next day saying he didn't try the exercise because he couldn't construct the figure.

The tendency of the day is to encourage constructional work in grades seven, eight and nine. If this is actually being done we would be foolish not to take advantage of it in the tenth grade. Some teachers advocate preceding demonstrative geometry by five or six weeks of intuitive geometry wherein various simple figures are constructed and discussed. To the writer it seems better to use intuitive and constructive work every day. That is the essential idea of the laboratory method. The teacher who is interested further in the laboratory method should examine the *Plane Geometry* by C. Addison Willis (Blakiston's Son & Co.) published in 1922, which is based on a method of "Experiment, Classification, Discovery, Application."

## GEOMETRY, A LABORATORY SCIENCE.

By F. H. Sutton,
*Principal Fresno Technical School.*

Mr. Wm. A. Austin, formerly of Fresno, California, is the author of a new work, *Geometry, a Laboratory Science.* The purpose of this article is to discuss the subject as presented by the author in previous numbers of *School Science and Mathematics,* and espceially as discussed in a paper by J. A. Nyberg of Hyde Park High School, Chicago, in this issue of this journal.

During the process of the development of the fundamental thought back of Mr Austin's plan and during the first few years of trial, the writer acted as instructor in the author's department in Fresno High School. This experience developed a new line of thought and each teacher now speaks from his own experience, coupled with the author's experience in the development of the process.

Mr Nyberg's discussion is very much to the point He seems to be in accord with the proposed plan of laboratory geometry and has adopted it in his school. There are two points, however, in Mr Nyberg's article which seem to be definite in their criticism. To quote Mr. Nyberg: "We do not expect the pupil to discover the conclusion for the text tells what is to be proved."

Our plan differs from this conclusion. We tell the student only those things which he can not be led to see for himself. In the spirit of activity which the student assumes, he finds that his demands upon the teacher are simply those of asking questions. Here is one of the strongest points of the book. The student takes the initiative, but by careful direction, he is led into the atmosphere of investigation and in the verification of known truths. To him the processes is as valuable as is a discovery to a student of research All students do not have the same ability in determining their verifications of facts when working computations and doing construction work. One of the greatest pleasures that a teacher has is that of observing the growth of this ability.

Mr. Nyberg comments upon the "laboratory method." We do not feel that our process of experimentation has to do with the verification of facts and truths only. We know that our students do a great deal of original thinking. This is our strongest justification for the term "laboratory method." A careful examination of the text will demonstrate that after a

short preliminary of mechanical processes the student is led directly into genuine and original thinking. As in the laboratories of chemistry, physics, biology and the other sciences, where a student is led into a spirit of investigation and real thinking, so is he led when following our new system of the presentation of geometry.

Prof. Rugg, of the Teachers' College, New York, says: "The chief purpose of instruction in geometry is the leading of pupils into the field of investigation and discovery. I agree thoroughly with the purposes of the work as you suggest them. Experimental work in the high school leads primarily to the verification of known laws. However, I personally would use the term, 'lavoratory method' for any work in which pupils are led to do original thinking."

We contend that we must not quible over the names of our methods, but must confine our argument to the proper development of processes which will lead the children under our care into the right fields of consistent thought.

We do not feel that Mr. Nyberg's second point is well taken. Why should a student waste time and material in carefully writing out all details of proofs? We consider that when we have asked a student in geometry to write out as many details as are given in the standard text that we have asked as much of that student as the law allows. We must not neglect the fact that a student gives a great deal of this information in his oral recitation.

We demand accurate and concise demonstrations from our pupils. We ask that the essential steps in the proof be given in clear form. Minor details remain between the lines, as it were. This condition will be found in any standard text.

Let us state that we feel keenly the student's inability to read and understand the average standard text in plane geometry. Experience has taught us that our laboratory method follows the psychological criterion and that the normal student is able to read the book understandingly. He needs very little teacher assistance. The day has come when our teachers act as directors, and mathematical treatises are no longer used as compilations of texts from which scientific sermons are preached.

We wish to emphasize four high points which were kept in mind by the author of the new book. They have to do with the modern view in mathematical text-book construction.

I. A study of the material definitely prepares the student

for entrance into the mathematical field which follows, and at the same time gives him an experimental insight into mathematical truths and assists him in their present day application.

II. Although the subject matter itself has been developed along the line of logical mathematical sequence, the new thought introduced will show that a psychological development, according to a child's way of thinking, has constantly been kept in mind.

III. By the introduction of what has been called the laboratory method, the child is led to the verification of fixed laws. He feels that he is led to the actual discovery of the mathematical truths.

IV. The pupil is led by this system to rely upon himself in the matter of genuine thinking. The original exercises and the construction problems are so arranged that a studnet's thinking is very definite and real. The teachers in the Fresno school system feel that the system of geometry discussed here meets the scientific requirements of the modern mathematics text.

*Note: A text book in Plane Geometry for use in teaching this subject as a laboratory science is now in the process of publication, and it will be off the press in a few months. The author of the book will take pleasure in giving the name of the publisher and in filing requests for sample copies of the text. Drop a card to Wm. A. Austin, Polytechnical High School, Venice, California.

## GEOMETRY, A LABORATORY SCIENCE

By JOHN O. PYLE,

*Carter H. Harrison Technical High School, Chicago.*

The method of teaching geometry developed by Mr. Wm. A. Austin, came to my notice a year or two ago. Also the textbook of C. Addison Willis came into my hand very early after its first appearance. The method of both these teachers impressed me as making a very significant turn in geometry teaching. Neither of these teachers, however, seemed to me to have gone quite far enough, nor to have emphasized the most important fact about the movement they were inaugurating.

The course in geometry presented by Mr. Austin is so nearly duplicated at Harrison High School in the mechanical drawing classes, that it possesses very little appeal. Moreover, many of the drawing classes have double periods, whereas the geometry classes have only single periods. Drawing figures to measurement, instead of free hand and merely pleasing the eye, has long been recognized by Harrison teachers as of great importance in

beginning classes. The over emphasis of this practice, however, may quite easily obscure the real nature of geometry and confuse the subject with that of mere mechanical drawing.

The actual good in drawing plane geometry figures to measurement as a basis for beginning study, is the fact that all plane figures drawn on paper or on the blackboard are as accurate and natural examples of such figures as occur anywhere in nature. This is not true of the figures of solid geometry. There no figure drawn on paper or on the blackboard is an accurate example of a solid figure. They are all mere pictures. This fact constitutes one of the difficulties for students of solid geometry.

Mr. Willis covers experimentally nearly the whole field of plane geometry; but in a way that seems to me very artificial and unreal. It is much like dramatizing an ancient classic that was written as a novel or a romance. The student is given a lot of practice, real work for that matter, but surely he must always be left with the feeling that nature and thought died with Euclid.

The significant fact, it seems to me, of the turn in geometry teaching, represented by the methods of Messers Austin and Willis, is the implication of admitting that the subject matter of geometry is susceptible of laboratory treatment. The method of the laboratory is to use observation, supplemented by carefully selected and controlled experiment, as a means of discovering and testing the more fundamental facts and laws of a particular science. That it has been eminently successful in all the other sciences everybody admits. That even there it has been abused, and sometimes barren of good results, especially in beginning classes, has been suggested in the articles appearing now and then by scientists in other fields.

The implication that the subject matter of geometry is susceptible of laboratory treatment is to make geometry a real science of nature, and group it with the other natural sciences. The authors cited appear not to have gone this length. The writer wishes they would. To do this, seems to him, the natural and proper culmination of their methods.

From this view point the laboratory merely supplements and aids the wider observation outside the class room. The student of geometry is merely exploring and learning the facts and laws of a particular aspect of objective nature. It is the same complex nature that meets him in the physics and chemistry classes, and on the street and in the home. The supreme motive is to learn the fundamental facts about this nature with a view to achieving as much control of what affects his experience as possible.

## SOME THOUGHTS ON METHOD IN SCIENCE INSTRUCTION.

By N. Gist Gee,

*China Medical Board of Peking, China.*

### Foreword.

These suggestions are offered with the hope that they may prove helpful to those who are giving thought to the quality of their teaching in the science subjects. We are conscious that nothing takes the place of the teacher and that his personality is the dominating feature in his teaching, but strong personality with good methods can accomplish much more than the same person with faulty methods. After all is it not the teachers function to inspire his students with a zeal to know, give them a method with which to work, and direct them in the formation of some purpose or ideal toward which they are to strive?

A number of educators have read through these notes and offered helpful suggestions and we are grateful for these. It has been difficult to keep the following notes from growing into many more pages, but we have withstood the temptation in the hope that more people would read a briefer statement of the case.

### 1. Preparation.

#### *a. By the Teacher.*

Contrary to the general feeling, preparation for one's class work is an indication of ability and good teaching rather than an evidence of poor scholarship. One must thoroughly master a subject matter before he can teach it. Yet it makes no difference how familiar a teacher is with the subject matter which he is to teach, he cannot properly present it without having studied his lesson again in the light of the knowledge of his class of students whom he is to teach. The teacher should spend much more time in preparation for his work than he expects the student to spend. Each new class with its new personalities must be considered. New and wider reading each year should characterize one's preparation even for the same work. Every live teacher is constantly adding to his library; new books and new current periodicals give many new sidelights even on old problems. Prepare not only background and material for presentation to the class, but also the best pedagogic method of presenting it.

Never allow a course to grow stale. Sustain interest by keeping yourself interested. Even in repeating a course, make the method of approach and presentation so new that a student taking the

course over would not recognize it. Change your text book, assign outside reading, keep the class conscious of the fact that the subject is a living one and that the last word has not been said upon it yet. Accumulate in the museum as much illustrative material as possible for use in class teaching. This is a phase of the work too often neglected. Any teacher with initiative can obtain much helpful material of this nature. All of this brings life to a class.

Have your own line of special interest in connection with your work. Nothing helps the class so much as to feel that the teacher is *a live student* of his own work as well as *a live teacher* of it, and that he is constantly growing himself as well as trying to get his students to grow. We dare say that no teacher is doing his best work without carrying his own problem of investigation at the same time.

Two definite lines of problems are suggested for the teachers of science; the first is that of scientific problems and along the line of some local interest.

Biologists might well turn their attention to intensive studies of their special localities. Little is known of the fauna and flora of China, and students quickly become interested in a study of their food supplies. Lists (and museum collections) of local plants and animals furnish much valuable scientific information and add interests and enthusiasm to class discussions. The instructor could well take some group of animal or plant life for special study along ecological or taxonomic lines.

Chemists will find much work to be done in the analysis of local minerals, coal, foods, oils, etc. Co-operative effort in attacking problems of this kind will add much to our knowledge along these lines and will lead the student to realize that his subject is a practical one.

Physicists have an interesting field in the application of the principles of their science to the industries by the Chinese. The field of new and better apparatus of local manufacture has great possibilities.

The second type of investigation is that of pedagogic study. How can we improve our methods of teaching? Can we not prepare better texts for use in China? Is it not possible to prepare better laboratory experiments and better laboratory methods? There is much room here for work of very real value.

*b. By the Student.*

The student prepares for the recitation from a very much

smaller knowledge and experience, and also from a much smaller reference library. His interest rarely takes him beyond his text, for he has assigned work that takes most of his time to prepare. His outlook into broader views than his text will come from the teacher's preparation, from the class discussions and from assigned reading. He should be held to the preparation of his work each day as a training. Memorizing the words of the text is not in any sense a preparation of the lesson. The students need to learn how to study in order to learn to think and to do.

2. The Class Room.

Good and correct lighting, comfortable seats, good ventilation, cleanliness and good cheer all add to the teaching possibilities. Arrange for plenty of blackboard space. System and orderly arrangement in a science class room or laboratory are a part of the essential background of training in the scientific method.

Arrange the windows so that they may be darkened easily for frequent use of the projection apparatus. Some appropriate adornment of the walls of the room gives a helpful touch to the surroundings. Large pictures of scientists on the walls of the room give a human touch to the science and furnish a reminder that your subject is a living, growing one.

3. Meeting the Class.

A pleasant, cheery greeting may often break down a barrier between the teacher and his students. Too formal a relationship often destroys spontaneity in the class. Get a response from the class even in the greeting. An effective teacher usually stands during the period and often comes out from behind the desk in order to get close to his students.

4. Number of Students in a Section.

Where recitations or class discussions are conducted, from twenty to thirty students can be handled with a fair degree of satisfaction. Even smaller numbers give better results and this is especially true in laboratory work. One instructor and one well trained assistant can direct satisfactorily a laboratory section of twenty-five students, but a larger number than this will be very difficult to supervise thoroughly.

Where the classes are small, attention can be given to students of superior ability. When classes are so large that it becomes necessary to have sections, it would be wise to divide the students on the basis of ability; this will make it possible to do more work with the better sections.

### 5. Class Conference.

(In large classes, where roll call consumes time, an assignment of definite seats to each student and rapid noting of absences by vacant seats saves time.)

That form of class conference is the most successful where the students have occupied the largest part of the period with their own thoughful discussions of the topic in hand.

The best discussion is the one in which the teacher takes the place of guide and does the least talking. The function of the teacher is to direct the activities of the students rather than do the work for them. Instead of being a dominating and restraining influence, he should be a helpmate and an inspiration to the group.

In a good class conference, interest in the textbook is subordinated to interest in the subject under discussion. It often adds to the interest to close the text and lay it aside entirely for the period. The discussion should grow out of the text rather than be bound down to it. A true teacher, moreover, who has prepared his materials beforehand, has the work of the hour outlined; but his plan is a flexible one, and he does not hesitate to alter it if the class interest demands it. "Lesson hearers," who follow the text blindly, build "cast iron" plans and never brook any interference with them.

Do not insist upon covering all of the assignment during the period. A small portion of it thoroughly discussed from every angle often does more good than a hurried discussion of many topics.

Stress the human side of your sicence in the class room work. Constantly connect it up with life by the application of principles to activities around you. Trace the development of the science from its beginnings and let the student feel that the present is only a stage in its development and that the future holds promise of even larger things. Call attention also to the close relationships between all the sciences and how one links up with another.

#### *a. Summary of Previous Work.*

In order to connect the last class conference or discussion up with the day's assignment and show that the subject under discussion is a connected whole, a brief summary of the salient points of the last period should generally be brought before the class at the beginning of the period. This may be done by a brief statement by the teacher or better by a few well chosen

memory questions, or by the previous assignment of a number of questions covering the desired points to be prepared by the class and a brief written test upon some one of them.

*b. Questions.*

Three types of questions are very serviceable. (1) "Memory questions," or those which test the preparation of the day's work or the memory of the work previously done; and (2) "thought questions," or those which stimulate the student to observation or thought and (3) "leading questions" or those which assist in developing quickly some new points of view for the class. Each type is valuable, but too great use of the first type leads to "lesson hearing" and a bored class, while well thought out questions of the second type introduce problems, the working out of which arouse, enthuse and inspire the students. Discreet direction on the part of the teacher enables the students to get the thrill of solving difficult problems by themselves and makes the recitation a delight instead of a task. As one of the main objects of teaching is to train students to think, a very large part of the recitation should be devoted to the second type of questions and the discussions growing out of them. As to the third type, it is often desirable to get quickly some new view points before the class and rather than consume the time of the class in developing it step by step, a leading question will obtain the desired results at once.

It is a good practice to ask a question first and then name the student you wish to answer it. This holds the attention of the entire class, as any one may be called upon. Following a regular order in calling upon the members of the class is not wise, because the students soon learn when their turn will come to be called upon and will make special preparation only for that time, and not prepare regularly.

*c. Answers.*

Questions requiring only a nod of the head or a "yes" or "no" are not generally good questions and do not give us any idea of what the student is thinking. Chance enters too largely into his answer.

Concert answers to class questions are of little service in large classes. They are best used for drill work and in small classes.

After a principle has been developed in response to questions, some application of this should be made in order to show its practical value and also to impress it upon the students' mind. Let the questions develop live class discussions and even debates.

*d. The Assignment of Special Work to Individuals.*

Let the best students take the lead now and then and have the responsibility of directing the work of the class during a period in the discussion of some problem which has aroused the enthusiasm of the group. Assign special topics or projects for individual reports—these should require reading or observation and should be made brief and pointed. Let the students feel that the success of the discussion depends to a large degree upon the part which they take in it.

*e. Projects.*

Often by the working out of some project which takes the class out of the building into the open for a period or two, new life may be infused into the class. Most interesting and valuable results have been obtained by the study of the markets in certain localities during different seasons of the year. The biology classes can learn the plants and animals used as food and the chemistry classes can learn methods of manufacture, food values, etc., from such a study.

*f. Use of Illustrative Materials.*

Use visual instruction wherever it is possible. Appeal through the eye as well as through the ear. Use freely museum materials. Classes may be interested in collecting and preparing illustrative materials which can be used repeatedly with later classes in the same subject. A diagram, a drawing, or an outline on the blackboard will often enforce a point most effectively. Make charts of everything and use student help in this work. Use the projection lantern constantly for slides, book illustrations, and films. Problems worked on the blackboard and discussed by the entire class bring the attention of the class to a focus upon these subjects. Demonstrations in the course of the class period often help to make clear points under discussion.

*g. Assignment of the Work for Next Period.*

It is generally difficult to find time for this at the last of the period when the class has responded properly to the stimulus of a well conducted conference; the assignment should show, as the summary did, that the subject is continued in another phase in the work for the next meeting of the class. Sometimes it is wisest to make the assignment (with the summary) at the beginning of the period and allow the class to come to an uninterrupted conclusion of the discussion at the end of the period.

### 6. Lectures.

Lecturing is the easiest method of using up the period, but is is generally the most ineffective method of teaching. An occasional lecture for the purose of bringing together a body of material that would not otherwise be accessible to the student, or for opening up or for summarizing and presenting as a whole some special subject in order to give the student a vision of the field to be covered, or for the purpose of making a direct application of the subject to conditions which exist locally, or for inspirational purposes, or for graduate students who are already mature, is most helpful; but the lecture in the hands of an inexperienced teacher with immature students is very ineffective. Lectures in which the material assigned to the students for recitation is simply reiterated by the teacher are worse than useless; they encourage the student to neglect his assignment and let the teacher do nis work for him.

The lecture method of teaching encourages college authorities to give teachers large classes and thus causes the students to lose the personal contact and influence of the teacher.

Most of the younger students find it difficult to take satisfactory notes, and consequently too often the lecture material is outlined, mimeographed and given to the student and he does not even give close attention to what is being said by the lecturer. A much better method, in case the proper texts cannot be had, would be to provide the outlines beforehand with references to a number of avaliable texts in the library and then conduct the period as a class discussion with the outline as the basis.

Lectures fail to develop self activity on the part of the student. They may assist the lecturer in clarifying his own ideas, but, too often, they allow the student to remain passive, and leave him with confused mass of vague and conflicting impressions.

#### *a. Demonstration Lectures.*

A teacher may wish to perform a number of experiments in his science for the class. A well planned lecture of this nature may enable the instructor to put before his students in a short time an organized group of experiments which they could not possibly perform, but which add much to the understanding of the principles under discussion. This type of lecture saves students time and gives them an opportunity to witness the superior technique of their teacher. Be careful to test out everything beforehand or botched and unsuccessful experiments will

break down the morale of even the best class. Apologies do not explain the teacher's failures.

### 7. Laboratory Instruction.

(Proper equipment of a laboratory is assumed.)

In most science work, the laboratory instruction should be the center around which the course is given, and not simply a lot of isolated, unconnected experiments or tests which have little relationship to the class room work. Constant use of laboratory work should be made in the daily discussions.

#### *a. Aims of Laboratory Work.*

As being the center of the course of instruction, the laboratory should contribute to the students advancement in several definite ways. He should learn how:

*1. To acquire information and useful habits of study.* Things learned by the student's experience in doing them, or seeing them, and as a result of his own activity, remain in his mind much longer and are known much more definitely than if he had read them in a book or had seen some one else do them. Although he cannot be expected to get all of his information in the laboratory, yet that obtained there makes it easier to get more from other sources and to discriminate in the accepting of information.

*2. To manipulate his apparatus or materials skilfully and with precision.* This needs to be a part of the training of every student and ability in this direction is a good criterion of the student's work.

*3. To observe closely.* He should know what to look for and be able to recognize it when he sees a definite result obtained.

*4. To reason logically.* After facts are observed, the student should be able to use these as a means of coming to the correct conclusions.

*5. To record accurately but tersely.* Often the good results of a successful experiment may be lost by the failure to make a proper record of the data obtained from the work done.

#### *b. Methods of Laboratory Work.*

Huxley has described for us very breifly the steps in the scientific method. They may be summarized in the four words:

1. Observation.
2. Induction.
3. Deduction.
4. Verification.

It would be most wise to create in the student the same atti-

tude toward his laboratory work which an investigator has in his work. He should be presented with a problem that is to be solved and he should attack it, under the teacher's discreet direction, as if it were a new problem, as it most likely is to him. He should see clearly, and draw his conclusions logically. From an accumulation of observations he soon gets to where he deduces certain ideas and then he must verify them.

In the laboratory, as in the class room the teacher makes his greatest contribution by being the inspiration of the group, and his efficiency is tested by the degree to which he makes the students do the work. He may direct, but he leaves it to the student to execute the work. He answers the students questions in most cases by asking other questions or by suggesting some activity on the part of the students. He praises the work of the student who originates or creates something. He suggests another trial, rather than condemns, when a student does not at first succeed. He is also careful to see that each student does his own work, thereby developing intellectual honesty and independence.

*c. Directions for Laboratory Work.*

There are two extremes in laboratory directions or outlines; in one case everything is told the student and he simply reads the directions and checks up the statements by his experiment. In the other case, the student is given the materials and told to find out what he can with them. The first creates careless habits of observation and a dependent attitude in the student while the second dazes him and often leaves him helpless. Somewhere between these two extremes is the type of laboratory outline that provides the proper stimulus to the eager young mind and guides his observation and his training in the scientific method by well chosen questions or problems. The previous training and the maturity of the student must be taken into consideration in setting laboratory exercises or problems, and we believe that a constant reworking of outlines is necessary, from year to year, constantly improving the technique and taking into consideration the personnel of each new class.

*d. Records of Laboratory Work.*

As a rule, too much time is given to writing of notes and the work itself becomes a secondary consideration. Make the laboratory work itself the prominent part and the notes only a brief, clear, and pointed record of results. Records should be

made in the laboratory and inspected and checked by the instructor before they are taken from the room. Some teachers never allow the student doing elementary work to take their note books out of the room except at stated periods. In biological work, often a well labeled drawing would satisfy the demands for records. When written notes are required they should be very concise. Some definite, uniform type of book for records simplifies the inspection of this work.

*e. Supervision of Laboratory Work.*

This is the most important part of a student's work and yet too many teachers are content to let this be done by the more or less untrained assistants or by junior members of the staff. Work in the laboratory is the most important part of the instruction, for it is here that habits of thought and skill are being formed, and it would be poor economy of time and energy to get the students started off all wrong and have to spend the rest of the years working to correct these early mistakes. Put the best teaching and supervision upon the beginning classes where ideals are being formed and where standards are being set which should be maintained throughout the entire scientific training of the students, as well as in his later life as a citizen. The laboratory instructor should not simply stand at one end of the room or sit at his desk to answer questions, but he should go around among the students giving directions, suggestions, or aid in correct manipulation of the apparatus or in thinking through the experiment for himself.

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**CAUSE OF PINK SAUERKRAUT FOUND BY EXPERIMENTS.**

Sauerkraut makers hate pink.

When a vat full of this product turns to this color it will not sell, for housewives are suspicious, and consequently the manufacturers sustain big money losses.

So pink to them is like red to short horn bulls. All this, however, may be changed by a series of experiments conducted at the University of Wisconsin at Madison under the direction of Dr. E. B. Fred, who has discovered that the tendency of the cabbage to turn pink during the progress of its transformation into sauerkraut is due to the presence of great numbers of wild yeasts or torulae. The greater the number of torulae in the vats the more pronounced the pink.

By proper precautions, Dr. Fred believes that this can be overcome. The favorable conditions for the development of wild yeasts are a supply of oxygen, a high temperature, high concentration of salt due to uneven distribution, and a high acetic or lactic acid content. Keep your vats air tight, he tells the manufacturers, distribute the salt evenly and keep down the temperature.

## SYSTEMATIC PROJECT WORK IN GENERAL SCIENCE AND BIOLOGY.

By Francis Day Curtis,

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The plan here presented for individual nature-study projects as an important part of the work in general science and biology was worked out by the author and his colleagues of the department of science during the course of several years' experimenting, with altogether about two thousand pupils, in Franklin High School, Portland, Oregon.

Early in the courses in general science and biology it was announced to the pupils that each must engage in an original investigation of some nature-subjects as one of the requirements of the years' work. The following conditions were to govern the work:

1. The nature-subject to be investigated was to be of the individual's choosing and might be the study of anything which took him *out of doors* for securing his materials—specimens for preservation or sketching, photographs, etc. Only rarely was a pupil permitted to select a topic, as "Constellations Visible from My Bedroom Window from October to May," which did not actually take him out of doors.

2. Each pupil must decide within a week and report to his teacher his project-subject. If upon consulting with his teacher the pupil considered his subject impracticable for his investigation he might choose another, but a definite date was set after which no changes of subjects were permitted. A list of suitable subjects was posted, from which the pupils might select if they desired, but its purpose was chiefly in order to give them an idea of the "sort of thing" they might pick out for study. Duplication of topics was neither encouraged nor discouraged among the members of a class, since the primary consideration was for each pupil to select the subject for study in which he was most interested; but pupils who selected the same topics were frequently encouraged to cover the same districts for the sake of "checking each others' findings."

3. Not only the subject for investigation but the district must be carefully delimited. For example, no pupil would be allowed to select as his subject, "Insects," or "Trees," or "Mushrooms," because these subjects are too broad to be covered thoroughly by any investigator during his entire life-

time; but the pupil might choose, "Butterflies Found in Bryant Park from September 15, 1922, to June 1, 1923," or "Varieties of Fruit Trees Growing in the District Bounded by 33, 35, Taylor and Washington Streets," or "Fall Mushrooms of the Franklin Woods." In short, the pupil must not only narrow his subject for investigation until he had succeeded in focusing his attention sharply and definitely upon some small division of some large class but he must also select for his study of this subject a district not so large but what he could be sure to cover it with the confident expectation of getting a specimen of every variety of the chosen sort obtainable in that district during the period of study. The pupil was urged therefore to choose at first a small district and if he subsequently found it practicable, to extend the district little by little, always covering it thoroughly and exhaustively. The clear establishment of and insistence upon this idea and ideal of a carefully delimited topic and district made possible the difference between aimless dabbling, more or less purposeless and valueless, and a thorough, systematic, and, although exceedingly elementary, dignified and respectable attempt at research.

4. As in more advanced investigations there must always be, for this elementary inquiry as well, a very careful preparation before the actual work with the problem could be intelligently attempted; and to insure that *every* pupil had made adequate preparation before beginning his actual collecting was one of the most difficult phases of the entire plan. If left to his own preferences and inclinations the pupil would usually begin gathering "specimens" at once and leave the mounting to a later period when he would invariably find his materials ruined, with little or no chance for securing more.

The first step following the selection of the subject for study was therefore for the pupil to formulate a careful and complete plan of work. Such a plan involved first, a thorough knowledge of the technique used by successful investigators of the same subject in mounting and preparing their materials and specimens; secondly, a mastery of the special vocabulary pertaining to the structure of the organisms the pupil proposed to study, so that he might not be handicapped subsequently in the use of a key and of other technical books which he would want to consult; and thirdly, a fairly broad knowledge of the nature, characteristics, habitat, etc., of the subject to be studied.

In the school library was a careful selection of suitable refer-

ence books,—moth-book, butterfly-book, reptile-book, mushroom-book, etc., indispensable volumes in *every* high school library,—and the home and city libraries might also be called upon to furnish some of this essential preliminary information. But whether the school-, home-, or city libraries offered help for a particular project or not, the pupil must first formulate a careful plan of work which he must then submit to his teacher for approval or suggestions for improvement; if the teacher felt that another teacher in the department was better qualified to advise upon that particular subject than herself, she felt entirely free to send the pupil to that teacher for assistance. The pupils were given a reasonable amount of class-time to devote to this preparation.

5. If the preliminary preparations by the pupil were thorough and adequate, he should subsequently be able to present his materials—preserved or mounted specimens, for example, in a workmanlike manner. A high standard of excellence for this phase of every project was insisted upon. But there must be more than mere collection of specimens; there must also be a serious attempt at classification. This was, of course, exceedingly difficult especially with the more immature pupils, but the pupils brought their difficulties to their teachers who helped them to understand the use of the various keys and guided them first in tracing through, if possible, some specimen the pupils already "knew" or some specimen which the teacher had already found easy to classify. This meant, of course, considerable preliminary work on the part of the teachers, especially those of less extensive experience and training, after the project-topics had been selected, to insure that they might be able to give some help to all.

6. The pupils were made to realize from the start that their teachers did not pretend to be, and were not to be expected to be, authorities upon all the various projects; that nobody could ever be expected to be an authority upon so many subjects, or even a small portion of the number which would be represented by all the projects chosen by a large class. The pupils were made to understand that probably any of the teachers of science would know considerable about some of the project-topics, and perhaps nothing whatever about others; that the teachers expected to learn from each pupil's work, something, perhaps many valuable facts. The teachers for their part (though this was always at first a severe trial to the

younger, less experienced ones) maintained the spirit of frankness and honesty regarding the limitations of their knowledge with respect to various topics; if appealed to for advice or help upon a project with which they were unfamiliar, the teacher worked with the pupil until her broader training and experience had enabled them together to secure enough information to assist the pupil over his difficulty and start him on. For example, one veteran teacher stated to another in the department, "John is studying spiders and couldn't get started on his classification of specimens. I told him I knew almost nothing about classifying spiders, but to bring his specimens and the spider-book and I'd work with him to see what we could learn together. We've put in at least an hour after school every afternoon this week and it has been hard work, but we've made progress; John has several specimens he is 'sure of,' and thinks he can go ahead now and succeed in classifying a number of spiders, anyway." Of course such a practice took much out-of-class time and energy, but their investment was more than repaid by the wholesome attitude which the pupils gained toward scientific investigation and toward their teachers, whom they came to know as just ordinary human beings who knew much more than they, but whose knowledge on many subjects was far from complete, and who were ready to learn with and from the pupils.

7. The pupils were warned that, simply because they had made their most careful classifications of their specimens did not insure that their results were always correct; that even the great scientists make mistakes. But each pupil must check with fresh specimens repeatedly and must expect to have his results checked by other "investigators." The final settling of "Who's right?" when two members of a class produced the same kind of fungus, each with a different classification, had a salutary effect upon the whole class.

8. The ideal of honesty in the work was considered all-important: every specimen collected should be of the pupil's own gathering, and every description submitted should be based entirely upon the pupil's own observation. There should be no trading of specimens, no passing on of projects; the pupils were made to feel that the actual number of specimens did not represent a worthy achievement by the pupil unless it was all his own honest work. Emphasis was repeatedly given to the fact that the pupil must be his own censor; only he would know

whether his efforts had been conscientious and his results commendable and honest. It was announced definitely, furthermore, that the teacher would not attempt to correct the results of the investigations; that each pupil's work must stand on its own merits, unchecked, except possibly by other pupil-investigators.

9. Each pupil should strive to become a real authority (this statement always evoked smiles at first but later received serious consideration) upon his particular subject, in so far as his district of investigation was concerned; of course, with such immature and inexperienced investigators this authority must necessarily be, practically without exception, qualitative; for example, if a pupil's subject were "Birds Observed in Our Orchard from September 15, 1922, to June 1, 1923," he must try to ascertain for himself and list every different *kind* of bird which visited his orchard during the given period and to know "better than anybody else in the world" which particular birds had been his visitors; if he were investigating "Mosses of Eastmoreland Grove," he should come to know with entire certainty how many different varieties of moss grew in that particular grove, however inaccurate his classification of some of the specimens and however rudimentary his knowledge of moss structure and function might be.

10. This was probably the most difficult idea in the whole plan to establish in the pupil's mind: that the final judgment of the excellence of the various projects would not be made by the teacher and the class upon the mere *number* or specimens, drawings, etc., exhibited, since it would be obviously much easier to collect and classify a considerable number of wild flowers from a certain field than it would be of moths from the same field; and eight classified specimens of fern might be a more worthy accomplishment with respect to a given district than double that number collected in a district many times as large.

11. The pupil might finally present his report in any form he chose; the more pride he took in the things he was doing the more apt he was to present his "findings" in an attractive way. Carefully prepared books containing beautifully mounted and partially classified collections of wild flowers were frequent; one boy with more or less success attempted to photograph the various birds which he described painstakingly in his reports; colored drawings of mushrooms accompanied by spore-prints were not infrequent; one boy produced a mild sensation by

presenting on the final day a number of carefully labeled fruit jars, each containing, preserved in formaldehyde, a different species of local snake.

At least one period, was devoted each month to individual conferences between the teacher and each pupil regarding his project; the teacher in a friendly way commended, counseled, and criticised. Interesting specimens and unusually good mounting or presentation of material were displayed for the approval of the class, and pupils who had something to tell which was likely to be of interest to the rest were permitted a few minutes in which to tell it. Some of the projects were necessarily seasonal, and the pupils who had selected these and therefore had nothing to report, and the rest when not actually conferring with the teacher, worked at special assignments during conference periods.

Most of the pupils who had elected general science in the ninth grade continued with biology in the tenth, and in this case were urged to continue during the second year the same project begun in the first, extending their territory and checking their previous findings. The further advantage was gained by this arrangement that there was a summer during the period covered by the project-work, in which to continue the investigations.

The final report day toward the end of the school year was keenly anticipated by both pupils and teachers. All projects were displayed, good, poor, and indifferent, with the names of their owners conspiculousy in evidence that each might be known by the fruits of his labors; every pupil in each class had to be represented by something. Teachers and pupils from the whole school visited the displays; projects of especial merit, both in the judgments of the teachers and the pupils were given places of honor for which important criteria for selection were

First, the condition of the specimens, or excellence of the drawings, or care with which the materials had been assembled for display;

Secondly, the relative difficulty of the project. Here the teacher used her influence to emphasize once more, that a large number of specimens, a "big showing" did not necessarily represent the most effort or the most commendable results; for example, six tiny labeled bottles containing, preserved in alcohol, "Parasites Found on Our Farm Animals," together with several pages of explanations and observations, was

given precedence over a collection of more than sixty wild flowers very carefully pressed and mounted, and with many accurately classified; this wild flower project was also considered inferior to another project consisting of eleven carefully drawn, described, and classified "Molds Found in My Home."

Thirdly, the pupil's own statement regarding how successful he considered he had been in obtaining all possible specimens to be secured in his district during the period covered.

Statements such as these were not infrequent on exhibition days:

"There are twenty eight different varieties of fruit trees in my district. I *know* because I got them all."

"There was no maiden-hair in my district, but a big clump grew just over the fence. I included a specimen with my project, but I was careful to state that it wasn't found *in* my district."

"James and I are going to trade project-subjects and districts next winter and check each other."

One serious lack in this school was the absence of facilities for making a permanent exhibit of the best projects, though on "Open House Nights" when the parents of the pupils visited the school en masse, it was always found possible to secure for exhibition the best projects for several preceding years to display along with current projects.

The results of this plan of project work were on the whole very satisfactory. A delightful relationship grew up between the pupils and their teachers, and even the least experienced and least adequately trained teachers gained confidence and power in finding that they were able with considerable success to direct their classes through the projects.

With respect to the pupils, though some of the lazier, less interested ones produced little or nothing particularly worth while and commendable in itself, even these doubtless gained important social values and a broadened outlook from their work, while a gratifyingly large number of the better equipped pupils produced results of surprising excellence and maturity. And of the more earnest ones, in meeting at times, as they inevitably must, obstacles insurmountable to their inexperienced efforts, in proceeding at others with more or less uncertainty and difficulty, and in feeling now and then the elation of success in some phases of their investigations, some at least gained, thus early in their training, a glimpse into the real meaning of scientific research.

## JUNIOR COLLEGE STUDENTS AS CRITICS OF TEACHING TECHNIQUE.

By VERGIL CLAYBOURNE LOHR,

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The material of this article is largely the expressions of the members of a class in Physics 2a-a Junior College course, given by the University High School of the University of Chicago. After the class had finished the final examination for the quarter, the following typed request was given the members: "With the assurance that your remarks will in no way affect your final grade, please be good enough to answer the following questions. (1) What are the chief weaknesses in the course in Physics that you have just taken? (2) What, if any, are the elements of strength in the course? A perfectly frank expression will be appreciated."

While the object in asking these questions was to gain information for purely personal use, the replies were so numerous and all together so enlightening, instructive and interesting that I am glad to pass them on to others who may not have been so fortunate in getting the same degree of frankness, and who may be interested in knowing just how keen our students are as critics of teaching technique. It is only fair to the students to say that not more than twenty minutes were given them to formulate and put their ideas in written form.

The course as given is intended for freshman students of the University of Chicago, who come to us with no high school physics. In this particular class there were a few senior college students and two graduate students. The work covers two quarters of twelve weeks each. In the first quarter, the topics usually given under titles of Mechanics, Magnetism and Electricity are covered, and in the second quarter those topics dealing with heat, sound and light are given.

The work of the year is arranged into teaching units as follows:—

( 1)—Preliminary—Units of Measurement.
( 2)—The Molecular Nature of Matter.
( 3)—Gravitational Forces.
( 4)—Force and Motion.
( 5)—Work and Power.
( 6)—Magnetism.
( 7)—Nature and Production of Electricity.
( 8)—The Effects of the Electrical Current.
( 9)—Heat Energy—Measurement of Its Effects.
(10)—The Transfer of Heat Energy.
(11)—Nature and Transmission of Sound.
(12)—Musical Sounds.

(13)—Nature and Transmission of Light.
(14)—Images.
(15)—Color.
(16)—Invisible Radiations.

The unit is intended to contain or embody a central fundamental concept, from which all related material may be conceived to radiate—a sort of hub of the intellectual wheel, as it were. Each unit is introduced with what we choose to call a pre-view. In this short lecture, the central idea of the unit is elaborated and the lines for investigation and study clearly pointed out, thus showing the relation of the several ideas to the main theme. Following this, the student is often required to reproduce in written or oral form, the gist of what the instructor has given, and is expected to be able at any time to show the relation of what he may be doing to the underlying idea embodied in the unit.

Following the pre-view comes a period of assimilation. Early in the course the student is impressed with the word "assimilation," and the distinction between "lesson getting" and assimilation is driven home. This period of assimilation varies from a few to several days, depending upon the nature of the unit and the difficulty of the material. For each unit the student has a stenciled sheet of reading references to the leading text books in physics. These references are given by topics with page or paragraph indicated. All material is in the school library and the reading assimilation is carried on entirely outside the class room. The class period—two hours each day—is given to lecture, oral and written quiz, discussion and laboratory work.

The laboratory work is done almost exclusively without the use of a manual. When it seems advisable to investigate a physical phenomenon, a law, or to determine a constant, the proposition is discussed informally and the need for investigation or information made real. The method of attack, required data, etc., is then decided upon, and after the student has prepared his own data sheet, the exercise is done. Thus no regular laboratory day or assignment is observed, but the laboratory work is made a distinct part of the assimilation process. A well organized written report of each laboratory exercise is required.

Following this period, opportunity for organized floor talks is given. Special topics are assigned which are inclusive enough to be a real test of complete understanding of the unit. On the unit, "Nature and Production of Electricity," such topics as;

"The Production of Electricity by Chemical Action," "The Modern Idea of the Composition of Matter and the Production of Static Electricity," "The Determination of the Relative Electron Gathering Power of Common Substances," etc., are given. It is regrettable that but little of this sort of thing was done because of lack of time.

With this brief summary of the plan of technique, the criticisms of the students are given without comment.

Elements of weakness in the course:—

"Not a sufficient check on reading assignments."

"Students not required to hand in definite assigned problems."

"Super intelligence of science teachers causes the student to have attacks of inferiority complexes and he loses confidence in himself."

"Chief weakness was that the class did not work to capacity."

"Laboratory write up too much of a feature."

"Over-crowding of the subject."—mentioned by three.

"Not enough open discussion of the material as presented in the texts."

"Too few problems in class and not enough individual recitation."

"Instructor spent too much time trying to get us to visualize." "I can understand Boyle's Law without visualizing bees."

"Too much time spent on individual's weakness. It should be the policy to let the individual be responsible for his own headway. A half hour in class given to an individual is an injustice to the others."

"Not enough floor talks by members of the class."

"In the recitation no help should be given a student when he is reciting. When he is studying he knows that he will get assistance over the difficult spots and therefore does not think it necessary to get it all perfect. You have told us many times that we would be required to recite with no assistance, yet no one ever did. If this were absolutely required the preparation and the recitation would be of more value."

Elements of strength in the course:—

The pre-view, mentioned by all and much favorable comment given.

The unit system, mentioned by seven.

The plan of laboratory procedure, mentioned by six.

The laboratory "write up", favored strongly by six. In this connection, I quote:

"By all means the most valuable asset which the course posesses is the plan of writing up the experiment. The fact that they must be handed in placed a spur on me until I became used to it, and learned to think the proposition clear through. If it had not been required, I doubt if I should ever have made a systematic review of the experiment. Several times I did experiments which were hazy in my mind, and on one occasion I did not know where it began or where it ended, but a half hour of thought invariably cleared my mind and made me see the entire proposition in its proper light. I am glad I had to do it."

I quote again: "The element of strength in the course as I see it, is the way in which the student has to work for himself. He is not checked up on publicly, but surely checked up on in such a way that he realizes that it is obvious that what he gets out of the course depends upon what he puts into it."

I quote from several on the pre-view:—

"We were given a pre-view on each unit. Step by step each part was explained in such a way that the student saw clearly just what steps to take in the new unit he was about to study."

"The pre-view is a fine thing, though I can't concieve of physics without it."

"The pre-view is fine. It is a good way to organize the material of physics to get a thorough look at the important details in an orderly manner".

"One of the things I have liked best was the pre-view given before each unit. They give one an idea in general of what he is about to study, so that one always sees what he is working towards."

"The pre-view keeps us thinking straight."

"The pre-view is, in my opinion, a very strong point. It is essential."

"The pre-view is another element of strength, because there are naturally so many things in the course which must be given a proper relation to the other things to give them significance."

I quote now from the comments of a graduate student.

"After having taken many college courses, under a variety of instructors and professors, I consider the Unit System, with the pre-view, the reading outlines with references, and the method in which the laboratory work was done as the outstanding features of the course. The unit system with what goes with it in this course is admirably adapted to hooking the unknown on to the known. The student always has some thing to go

back to, on which he can hitch the new ideas gained, and has also a starting point from which he can branch out individually. Assimilation has been emphasized in the course and rightly so. If this power is to be developed or trained I know of no system better suited than the one employed in this course. It both encourages and directs thought and offers limitless opportunities and possibilities for individual investigation on the part of the student. It places the instructor in the position of a real advisor and helper rather than a task master whose chief interest is to have problems six to sixty solved, no matter what the thought process was.

"The method of conducting the laboratory work is a point of strength. When one can go to the laboratory, knowing exactly what he wants to investigate and can do the experiment without a manual, he knows what he is doing and why he is doing each thing. That is training personal investigators—scientific men, who know what they are about and how to interpret their results. But with such a system, I fail to see the necessity of the detailed write ups. Let them be merely data sheets with conclusions reached, for it seems to me that the way the experiments are conducted, the student ought to be able to explain what he has done and need not be tested on that. Stick to the method that was used in the laboratory! Too much of elementary science is of the 'cook-book' variety."

---

**SCIENTISTS OBSERVE ARMY OF CENTIPEDES ON THE MARCH.**

The migration of a vast army of "thousand-leggers," marching through the desert, is the unique sight reported in "Science" by Professors J. M. Thuringer and O. B. Jacobson of the University of Oklahoma.

They were driving through a desert stretch in New Mexico, devoid of vegetation or even of large rocks, when they observed small black objects along their path. At first they paid no attention to them, but when they became so numerous that the wheels of their Ford ran over one every yard they stopped long enough to examine them. They found that they were large centipedes, all apparently moving in the same direction. What these crawling beasts were doing in this desert place, where they came from, why they left their old home, and what they expected to find in a new one were questions the two scientists did not stop to ask.

"We thought of possible mishaps to our 'Lizzy,'" they report, "the thirsty radiator and perhaps a forced stay in this most uninviting, inhospitable environment, and drove on. Fully ten more minutes were consumed in driving through this sea of centipedes, and countless victims remained behind in our tracks. We breathed a sigh of relief when the scattered outposts were reached and the burning sands alone reflected the heat of the brilliant desert sun."

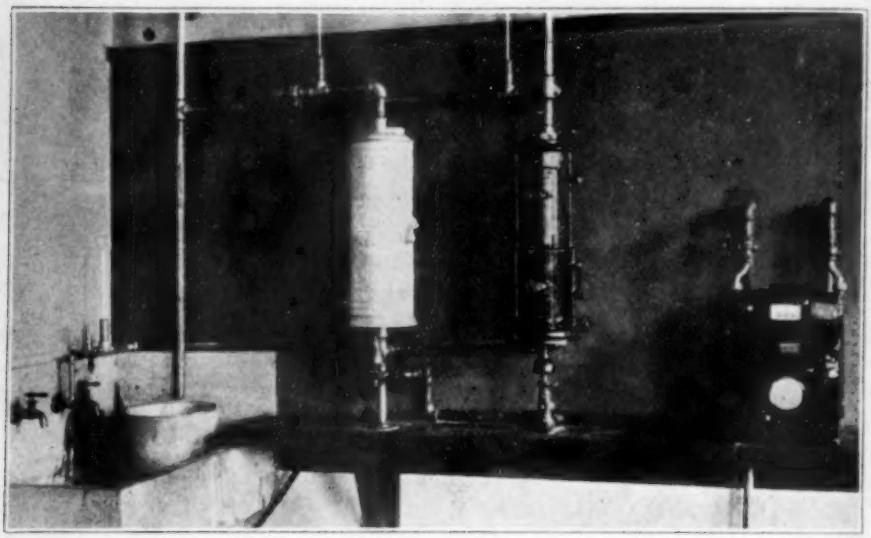
Migrations of butterflies and other insects have been observed many times, but little or nothing is known about mass travel on the part of lower forms of life like centipedes.—*Science Service.*

## A LABORATORY EXPERIMENT ON THE EFFICIENCY OF DIFFERENT TYPES OF WATER-HEATERS.

By H. Clyde Krenerick,

*North Division High School, Milwaukee, Wisconsin.*

After, various troubles with two different Junker's calorimeters in determining the fuel value of gas, and unsatisfactory results when performed by students in the laboratory, the nature of the experiment was changed from one of verification to one of application.



Two different types of gas water heaters that were most extensively used in the city and a gas company gas meter were installed in the laboratory as shown in the picture. One of the heaters is the coiled pipe type while the other is the disc type.

The directions given to the students for performing the experiment may be of interest to some. Because of its practical phase, the experiment has always appealed to the student and to others that have seen the apparatus.

### Directions

Study carefully the apparatus and note that the water may be passed through either heater at will by means of the stop cock back of heater.

To test the Sands heater open the stop cock in water pipe back of heater and close stop cock back of the other heater. Next open the stop cock near the water faucet at smk. The proper rate of flow of water will be obtained by turning handle of cock 45 degrees.

Light the gas in the Sands heater. To avoid an explosion apply match and turn on gas at same time. Regulate the flames by having the gas

cock two-thirds open. The test should not be made until the thermometer above the heater gives a constant reading.

To make the test, the amount of water passing through while exactly three cubic feet of gas are burned must be determined. One student will push the pail under the water exit pipe and remove it at the signals of student observing the meter dials. Both thermometers should be read at the beginning of the test and immediately at the close. The averages should be taken as the final readings.

From the weight of water in the pail and the change of temperature of the water passing through the heater, compute the number of B. T. U. received from the three cubic feet of gas. With the fuel value of gas as 560 B. T. U. per cubic foot, compute the input and efficiency of the heater. Repeat the experiment in every detail using the Duplex Jiffy heater.

With gas at $.75 a thousand cubic feet, compute the cost of heating 10 lbs. of water from 72 degrees to 212 degrees Fahrenheit with each heater.

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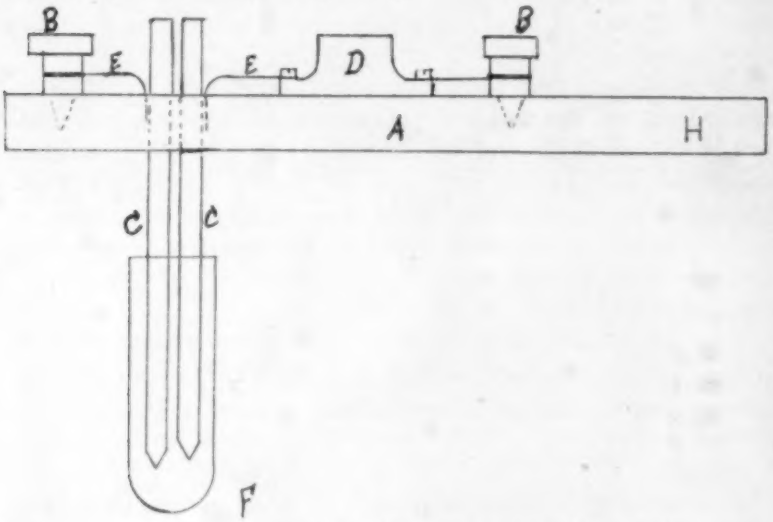
## THE IONOSCOPE.

By LARRANCE PAGE,

*Berkeley, California.*

The sketch shows the construction of the Ionoscope, an "instrument" for showing the presence of ions by means of the electric current which they carry.




All dimensions are rough, to be varied according to circumstances. A is a piece of board ¾x2½x10 inches. B, B are binding screws—any kind of electric connectors. C, C are two dense carbon rods ("pencils") ¼ inch in diameter, 5 inches long. D is a lamp-base, "temporary receptacle." The carbons are inserted into round holes in the board, about ⅛ or 3/16 inch apart. These holes should be accurately parallel. The

wires E, E make electric connections as shown; their ends fit in small grooves in the sides of the carbon-holes. F is a beaker or test-tube for holding the solution whose ionization, (conductivity) is being tested. If the instrument is carefully made, a 6x¾ test tube may be used. A piece of lampcord leads from the binding screws B, B, to a source of electricity. A lamp bulb is inserted in the base D. A clamp and a stand hold the instrument at a convenient height. The end H is to be held by the clamp. It is well to have several pairs of carbons, say three pairs. Now for experiments.

Experiment I.

Use dry clean carbons. Fill F with fine dry salt, almost any salt, say table salt. The absence of any glow in the lamp shows lack of ionization. Wash all salt off with distilled water. Dry carbons with filter paper or paper towel before trying another salt.

Experiment II.

Put clean distilled water in tube, raise around carbons till they are half submerged. Lamp does not glow, little or no ionization.

Experiment III.

Put any electrolyte (in solution) in tube F, raise till carbons are immersed. Bright glow in lamp shows abundance of ions. Any number of electrolytes may be tried, but the carbons should be well washed with distilled water before each trial. This washing is easily done by raising and lowering a tube of water around the carbons, changing the water and repeating till there is no glow in lamp.

Experiment IV.

Test sugar solution as in Exp. 3. Various "organic" substances in solution may be tested, both with water and with other solvents, such as alcohol and benzene. Also salts in alcohol, etc.

Experiment V.

This requires a direct current. If a miniature lamp and base are substituted for D, a few dry cells will serve. Put a solution of copper sulphate in F, and copper plate one carbon. Interchange carbons or the lead-in wires and remove the copper from the one carbon and plate it on the other one.

These experiments with suitable explanations stir up a lot of interest in the theory of ionization; they make a "dry" chapter very interesting. This form of apparatus is new, and much more convenient than that usually described in books.

## PLANTS GROW QUICKLY AFTER ETHER SPREES.

No longer will useful plants be allowed to sleep out their long winter sleep if a discovery announced to Science Service by Prof. David Lumsden of the Federal Horticultural Board becomes the common property or nurserymen, amateur and professional gardeners and even farmers. For he has found that if given a "shot of dope," either by the inhalation of hypodermic method they may be awakened as if by an alarm clock and set to their work of growing and producing flowers or fruit for the pleasure or profit of man.

The drug used in his experiments was the common ether of the hospital operating room, but instead of putting his plant subjects to sleep it woke them up. They liked it and seemed to thrive after just one treatment. For example, some plants were taken from outdoors in midwinter when they had to be dug from the frozen ground with picks, were given an overnight ether debauch and the next morning, shoots of an average length of one-eighth of an inch had sprouted. Kept indoors they continued to grow and flowers were produced weeks in advance of the usual blossoming season.

Roses were taken from the frozen ground and given a hypodermic injection of the same drug. Not only did they sprout and grow but, more important still to the indoor gardener, they were immune to all the ordinary plant diseases that make indoor rose culture a practical impossibility except in large greenhouses. Professor Lumsden has had roses in February, just six weeks from the time the plant was given its stimulating injection.

Only a very small quantity of ether is needed. In the inhalation method the plants are put in an airtight chamber containing 27 cubic feet of space. Five cubic centimeters of ether, or about a tablespoonful, are then introduced and the chamber sealed. Only about twelve hours exposure to the fumes is needed, and then the little plants are wide awake and growing.

In the hypodermic method Professor Lumsden made use of that sometimes formidable weapon, a woman's hatpin. With this a puncture about a quarter of an inch deep was made at the base of the stem of the plant where it joins the root. Then an ordinary hypodermic needle was introduced and half of one cubic centimeter of ether injected. This is the method which was generally used with woody plants such as roses or lilacs.

One of the important applications of this whole process, according to Professor Lumsden, is that using either method of drugging the plant, every single latent bud or shoot is brought to life. That is not Nature's way, as usually only one of three or four ever grows. This maymean much in the culture of plants such as dahlias or potatoes which are grown from tubers. If every latent bud on these tubers could be made to grow they could be cut into smaller pieces, and expense of seed saved. What is more, Dr. Lumsden believes that the plants would be more vigorous.

For he is working now to see if these ether treatments, especially the hypodermic sort, do not impart a lasting vigor to the plant, enabling it to resist disease. His experiments with roses strongly indicate this. If they are confirmed, ether "shots" will with plants take the place of the various forms of vaccinations to which the would-be healthy human is now subjected.

Finally, there is a mystery in this whole affair which science may some day solve, but of which it now knows little. Ether temporarily stimulates and then profoundly depresses all animal life. With plant life in moderate doses it is apparently all stimulation with no depression and no injurious after effects, but, instead a lifelong increase in strength and endurance. If science can learn why this is so, much light will be thrown, Professor Lumsden says, upon the secrets of physiological growth.

## PROBLEM DEPARTMENT.

CONDUCTED BY J. A. NYBERG,
*Hyde Park High School, Chicago.*

*This department aims to provide problems of varying degrees of difficulty which will interest anyone engaged in the study of mathematics.*

*All readers are invited to propose problems and solve problems here proposed. Problems and solutions will be credited to their authors. Each solution, or proposed problem, sent to the Editor* should have the author's name introducing the problem or solution *as on the following pages.*

*The Editor of the department desires to serve its readers by making it interesting and helpful to them. Address suggestions and problems to J. A. Nyberg, Hyde Park High School, Chicago.*

### LATE SOLUTION.

837. *A. N. David, Judson College, Rangoon, India. Leonard Carlitz, Philadelphia, Pa.*

838. *Leonard Carlitz, Michael Goldberg, Philadelphia, Pa. A. J. Haynes, Bishop Cotton School, Bangalore, India. George Sergent, Guatemala, Central America.*

839. *A. N. David. George Sergent.*

Several readers having asked to see more of the details of the solution of the cubic equation, $x^3-432x+1152=0$, in problem 839, the following solution by George Sergent is given.

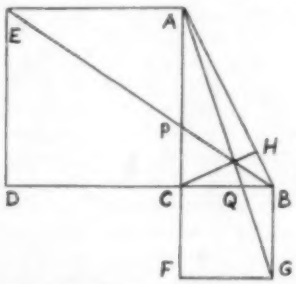
Comparing $x^3-432x+1152=0$ with $x^3+3px+2q=0$ we see that $p=-144$ and $q=576$. Since $q^2+p^3<0$, Cardan's formula can not be used, the roots appearing under imaginary forms although all three roots are real. In this case the 3 roots are givenby the formulas $x_1=2\sqrt{-p}\cos\frac{1}{3}\theta$; $x_2=-2\sqrt{-p}\cos(60+\frac{1}{3}\theta)$; $x_3=2\sqrt{-p}\cos(120+\frac{1}{3}\theta)$ wherein $\cos\theta=q/\sqrt{-p^3}$. (These formulas are found by putting $x=k\cos\frac{1}{3}\theta$ and then establishing the relations between the equation $x^3+3px+2q=0$ and the identity $\cos^3\frac{1}{3}\theta-\frac{3}{4}\cos\frac{1}{3}\theta-\frac{1}{4}\cos\theta=0$). In this problem, $\cos\theta=576/1728=\frac{1}{3}$, or $\theta=70°\ 31'\ 43.6''$. The values of $x_1$ and $x_3$ will not satisfy the problem and $x_2=2.71289$.

### SOLUTIONS OF PROBLEMS.

841. *Proposed by Walter H. Carnahan, Bloomington, Ind.*

In $\triangle ABC$, $\angle C=90°$. On AC the square ACDE is constructed, and on BC the square BCFG. The altitude to the hypotenuse is CH. Prove that the lines BE, AG, CH are concurrent. [I find this problem written on a fly leaf in a book purchased from the library of the late Professor Beman of the University of Michigan. *Proposer.*]

I. *Solved by R. T. McGregor, Elk Grove, Cal.*




Let EB cut AC at P, and AG cut BC at Q. Then $\triangle APE\sim\triangle BCP$ and hence $CP/PA=BC/AE$. Also $\triangle AQC\sim\triangle BGQ$ and hence $BQ/QC=BG/AC=BC/AE$.

Also $AH=AC^2/AB$ and $HB=BC^2/AB$.

Hence $CP\times AH\times BQ/PA\times HB\times QC=1$, and by Ceva's theorem, BE, AG and CH are concurrent.

(This proposition is stated, without a proof, on page 17 of Casey's "*Sequel to Euclid.*")

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Similarly proved by *D. L. MacKay, New York*, and *George Sergent.*

II. *Solved by H. Sohon, Hasbrouck Heights, N. J.*

Use the point C as the origin of co-ordinates, CB as the positive $x$ axis, and CA as the positive $y$ axis. CB = $a$. CA = $b$. The co-ordinates of the various points are: A(o, $b$); B ($a$, o); C (o, o); E (—$b$, $b$); G ($a$,—$a$).

The equation of AG is $ay+(a+b)x = b$

The equation of BE is $bx+(a+b)y = ab$

Since CH is $\perp$ to AB, its equation is $by - ax = 0$

The intersection point of AG and BE is:

$$x = ab^2/(a^2+ab+b^2),\ y = a^2b/(a^2+ab+b^2)$$

and these co-ordinates satisfy the equation of CH. Hence the lines are concurrent.

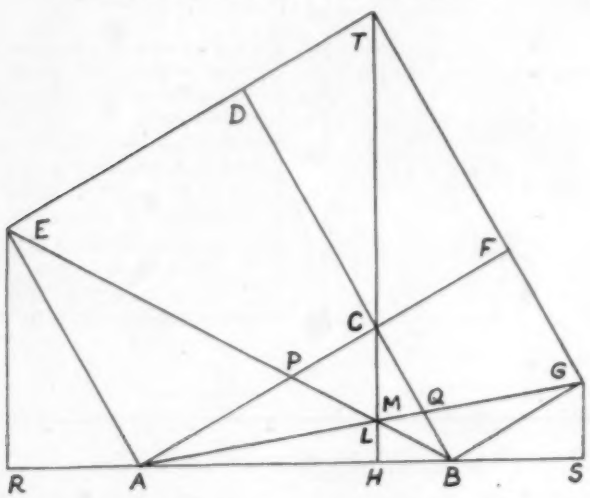
Similarly solved by *T. E. N. Eaton, Redlands, Cal.; Walter C. Eells, Whitman College, Walla Walla, Wash.; C. E. Githens, Wheeling, W. Va.;* and *Michael Goldberg. W. C. Eells* adds that if $a = b$, that is, if the triangle is isosceles, then the three lines AG, BE, CH are medians and the intersection point is the center of gravity of the triangle.

III. *Solved by R. A. Wells, Park College, Parkville, Mo.*

Let L denote the intersection of AG with CH, and M denote the intersection of BE with CH. We can first prove that BS = HC = AR. Then by similar triangles,

$$HL = GS \cdot AH/AS = HB \cdot AH/AS = CH^2/AS$$
$$HM = RE \cdot BH/BR = HB \cdot AH/BR = CH^2/BR$$

Hence HL = HM, and L and M coincide.




IV. Solved by the *Proposer.*

The proof (abbreviated by the editor) consists in prolonging GF and ED to T, and drawing TA and TB. Then prove that AG, BE, and CH (proved to coincide with CT prolonged) are perpendiculars to the three sides of the $\triangle$ ABT, that is, are altitudes of a triangle and hence concurrent.

Also proved trigonometrically by *Leonard Carlitz.*

The editor thinks this has been an unusually interesting problem and is making use of it in his daily work. The figures are on the blackboard with the instruction "Find as many relations as you can, such as similar triangles, proportions, equal lines, etc." The third year algebra class will solve the set of literal equations given in the second solution, and the equations are used to explain what "analytic geometry" means.

842. *Proposed by Arthur H. Lord, Classical H. S., Lynn, Mass.*

Under what conditions will the three sides of a right triangle, the alti-

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tude on the hypotenus, and the segments of the hypotenuse all be integral? be rational? [The problem about the integral character of the sides of a right triangle has been frequently discussed. In this problem the altitude and the segments of the hypotenuse are also to be integral, or rational.—*Ed.*]

*Solved by C. E. Githens, Wheeling, W. Va.*

In the $\triangle ABC$ with the altitude AD to the hypotenuse, let $AB = a^2 - b^2$, $AC = 2ab$, $BC = a^2 + b^2$. Then the altitude AD is $2ab(a^2 - b^2)/(a^2 + b^2)$; BD, one segment of the hypotenuse is $(a^2 - b^2)^2/(a^2 + b^2)$; and DC, the other segment is $4a^2b^2/(a^2 + b^2)$. These values are all rational if $a$ and $b$ are. In order to make the altitude and segments integral, each of the above expressions should be multiplied by $(a^2 + b^2)$.

Also solved by *Leonard Carlitz; Michael Goldberg.*

843. *Proposed by J. F. Howard, San Antonio, Texas.*

Ten persons each name a number not greater than 10. Find the chance (1) that no two persons shall name the same number, (2) that all ten shall name the same number.

Solved by *Leonard Carlitz, Philadelphia, Pa.*

(1). Not counting 0 there are 10 numbers not greater than 10. The 1st person may select any one of 10 numbers. The chance that the 2nd select a different number is $9/10$. The chance that the 3rd select a still different number is $8/10$, etc. The chance that the 10th person select a different number is $1/10$. Hence the chance that no two persons select the same number is $9!/10^9$.

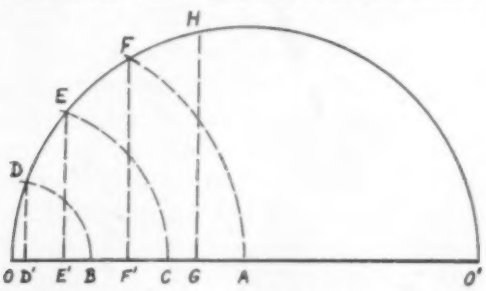
(2). The first person may select any one of 10 numbers. The chance that the second person choose the same number is $1/10$. The chance that the third person choose the same number is again $1/10$. Hence the chance that all select the same number is $1/10^9$.

If 0 is considered as a possible choice then the answers to (1) and (2) are, respectively, $10!/11^9$ and $1/11^9$.

Also solved by *Michael Goldberg; H. Sohon; George Y. Sosnow, Newark, N. J.*

844. *Proposed by Harry Frye, Tullahoma, Tenn.*

Prove the correctness of the following method for finding the radius of a circle whose area is the sum of the areas of several circles:




Let OA be the radius of the largest of the given circles and OB, OC the radii of the other circles. With A as center and AO as radius draw an arc intersecting the circles at D, E, and F. From D, E, and F draw the perpendiculars DD', EE', FF', to OA. From F' measure $F'G = OD' + OE'$. At G draw a perpendicular intersecting the arc at H. Then the line OH is the desired radius.

*Solved by D. L. Mackay, New York, N. Y.*

$OD^2 = OO' \times OD'$; $OE^2 = OO' \times OE'$; $OF^2 = OO' \times OF'$

Hence, $OD^2 + OE^2 + OF^2 = (OD' + OE' + OF')OO'$

$= OG \times OO' = OH^2$.

Multiplying each term by $\pi$ so that each term will represent the area of a circle, we see that OH is the radius of the circle whose area is the sum of the other areas.

Also solved by *Leonard Carlitz; T. E. N. Eaton; Walter C. Eells; George Sergent.*

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845. *For High School Pupils. Proposed by Louis Sklar, Philadelphia, Pa.*

Three equal circles are tangent to each other. The area between the three circles is 1 sq. in. Find the radius of the circles.

*Solved by Leland J. Shell, Wilmington H. S., Wilmington, Cal.*

Let $r$ be the radii of the circles. The area of the triangle formed by the centers of the circles is $r^2\sqrt{3}$. The area of the three sectors is $\pi r^2/2$

Hence $r^2(\sqrt{3}-\pi/2) = 1 \qquad r = 2.493$ (approx.)

Also solved by *Mildred Day, Northeast H. S., Kansas City, Missouri,* and by *Webb Van Dyke, Christian H. S., Grand Rapids, Mich.*

## PROBLEMS FOR SOLUTION.

856. *Proposed by D. L. MacKay, New York, N. Y.*

Prove problem 841 in this issue, when the $\triangle ABC$ is scalene.

857. *Proposed by F. A. Cadwell, St. Paul, Minn.*

Construct the triangle having given one side, $a$, the opposite angle, A, and the distance, $e$, between the center of the inscribed circle and the center of that escribed circle which is opposite A.

858. *Proposed by Norman Anning.*

If $x$, $y$, $z$ are unequal and if

$$\frac{xyz}{y+z} - x^2 = \frac{xyz}{z+x} - y^2$$

show that each equals $\dfrac{xyz}{x+y} - z^2$

859. *Proposed by C. E. Githens, Wheeling, W. Va.*

Given a quadrilateral, no two sides of which are equal or parallel, but with the diagonals perpendicular to each other. Find integral values for the sides of the quadrilateral and the segments of the diagonals.

860. *For High School Pupils. Proposed by I. N. Warner, State Normal School, Platteville, Wis.*

On a certain invoice for some goods, a total discount of 38.8 per cent was given. This was the result of a series of three discounts, the first 20 per cent, the second 10 per cent. What was the third discount?

## SCIENCE QUESTIONS.

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*Please address all communications to Franklin T. Jones, 10109 Wilbur Avenue, S. E., Cleveland, Ohio.*

## PROBLEMS AND QUESTIONS FOR SOLUTION.

454. *Proposed by Albert Giles, Cleveland, Ohio*

(1) If an engine (truck engine) at 800 R. P. M. runs satisfactorily on a lean mixture and gives 33 miles per gallon, and the same engine at 800 R. P. M. runs satisfactorily on a rich mixture but only makes 21 miles per gallon; how much more power do we get with the rich mixture over the lean?

455. *Proposed by the Editor.*

What changes would you like to see in the Science Questions Department? (Don't hesitate to say what you think.)

## SOLUTIONS AND ANSWERS.

448. *Proposed by Fred S. Jones, Hastings, Mich.*

How silver a mirror without using Ethyl alcohol?

# The New Birch Rapid Calculation Lessons

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**—1924—**

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Will Mr. Jones try out the answers from Mr. Taylor and from Mr. Gaertner and report?

449. *Proposed by R. Beatrice Miller, West Philadelphia High School for Girls, Philadelphia, Pa.*

How can a gravity cell be filled with the least possible mixture of the zinc sulphate and copper sulphate solutions?

*Answer by A. A. Knowlton, Reed College, Portland, Ore.*

Question 449 in the number of School Science which has just come in suggests another which perhaps need not be printed unless to call attention to the amount of dead stuff which loads our texts.

Question 449 reads, "How can a gravity cell be filled with the least possible mixture of the ..... solutions?"

The one I have in mind is, *Why fill a gravity cell?* As I see it, the gravity cell, and most other primary cells, should be studied in connection with medieval history or perhaps paleontology rather than with courses in physics.

*Answer by the Editor.*

The simplest way to fill a gravity cell is simply to pour water slowly on the zinc. Put the cell in series with another similar cell or a resistance of say 10 ohms. Let the combination stand over night and any mixing of solutions will clear up. The loss of zinc is small.

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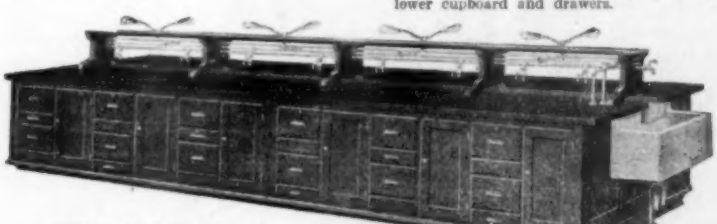

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## PROGRAM FOR THE FOURTH ANNUAL MEETING of the SCIENCE SECTION of the ASSOCIATION of COLLEGES and PREPARATORY SCHOOLS of the MIDDLE STATES and MARYLAND to be held at CORCORAN HALL, GEORGE WASHINGTON UNIVERSITY, WASHINGTON, D. C. on SATURDAY, NOVEMBER 29, 1924, at 9:45 a. m.

**PAPERS**—1. **Science Tests: The New Type versus the Old Type.**
Mr. Leighton K. Smith, Department of Chemistry, Wilmington High School, Wilmington, Delaware.

2. **The Teacher's Relation to Research.**
Dr. E. A. Eckhardt, Physicist, Bureau of Standards, Washington, D. C.

3. **A College Course for Students with High School Training in Chemistry.**
Miss Quaesita C. Drake, Professor of Chemistry, Women's College, University of Delaware, Newark, Delaware.

**ADDRESS**—11:00 A. M.—**Chemistry in Our National Life.**
General Amos A. Fries, U. S. Army, Washington, D. C.
Questions and General Discussion will follow the address.

**BUSINESS MEETING**—Reports of Committees.
Election of Officers.
Discussion of revision of the Constitution of the Section.
2:00 p. m.
Meetings of the Council and of newly appointed committees to discuss plans for the next year.

The Science Section was organized in 1921 at the thirty-fifth annual Convention of the Association of Colleges and Preparatory Schools of the Middle States and Maryland "to bring about active co-operation between the colleges and preparatory schools in improving the teaching of science." Persons interested in the teaching of science in the Middle States and Maryland are invited to attend the meeting and to become members. The annual dues are fifty cents, payable at the time of the annual meeting. It is suggested that for their own convenience members pay for two years or more at one time.

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## CHICAGO MATHEMATICS CLUB.

Historical Note: The Chicago Mathematics Club has been in existence for eleven years. The club was started by C. M. Austin of Oak Park in January, 1914. The Presidents with their term of office are given herewith: C. M. Austin, Oak Park, 1914-1916; John R. Clark, Chicago Normal, 1916-1918; W. W. Gorsline, Crane Junior College, 1918-1920; M. J. Newell, Evanston, 1920-1921; H. C. Wright, University High, 1921-1922; Everett Owen, Oak Park, 1922-1923; Olice Winter, Harrison Tech., 1923-1924.

### Summary of Programs for 1923-1924.

October 26, election of officers: President, Olice Winter; Secretary-Treasurer, Marx Holt; Recording Secretary, Edwin W. Schreiber. "Mathematic Classroom Technique," Prof. C. W. Meyer, Marx Holt, A. M. Allison, C. E. Kitch. Attendance, thirty-nine.

November 16, "Some Mathematical Aspects of Modern Astronomy," Prof. F. R. Moulton, University of Chicago. Attendance, forty-one.

December 14, "Resolved that the Ohio Requirements for Mathematics in High Schools be Adopted in the Chicago Area." Affirmative, B. Laughlin, J. C. Piety; negative, S. J. A. Conner, O. M. Miller. Attendance, eighty-four.

# School Science and Mathematics

Member of the Educational Press Association of America

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**MANUSCRIPTS.** Contributions on Science and Mathematics Teaching are invited. Articles must be written on one side of the sheet only. All illustrations must be drawn or written in jet black on a separate sheet of manuscript. Contributors are requested to write scientific and proper names with particular care. Manuscripts should be sent to the Editor of **School Science and Mathematics, 5517 Cornell Ave., Chicago,** or to the proper departmental Editor. Books and pamphlets for review should be sent to the Editor. To insure insertion in any number, manuscript must be in the editor's *possession not later than the 20th of the second month before* publication.

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January 18, "Mathematical Phases of Modern Telephone Work," Mr. Wilber Roadhouse, Transmission Engineer, Am. Tel. and Tel. Co. Attendance, thirty-four.

February 23, joint meeting with National Council of Teachers of Mathematics.

March 21, "Mathematical Instruments of 200 Years Ago," illustrated with lantern slides, Edwin W. Schreiber, proviso. Attendance, thirty-one.

April 17, "Grand Powwow on the Report of the National Committee," representatives from Crane, Evanston, and Oak Park. Attendance, thirty.

May 16, "Algebra," Superintendent E. E. Arnold, The Pelhams, New York, a joint meeting with the Women's Mathematics Club of Chicago. Attendance, twenty-eight.

RECORD OF ATTENDANCE.

| Name | Name of School | Number Attend. |
|---|---|---|
| Allison, A. M. | Lake View | 7 |
| Austin, C. M. | Oak Park | 4 |
| Breslich, E. R. | U. High | 2 |
| Cavanaugh, A. W. | Lewis | 3 |
| Conner, S. J. A. | Harrison | 3 |
| Cobb, H. E. | Lewis | 1 |
| Coultrap, M. W. | N. W. College | 2 |
| Espay, C. W. | Lindblow | 1 |
| Franks, P. R. | Proviso | 1 |
| Foster, F. M. | Oak Park | 2 |
| Gorsline, W. W. | Crabe Col. | 4 |
| Graham, W. B. | Pullman | 1 |
| Holt, Marx | Crane Col. | 5 |
| Johnson, J. T. | Normal | 2 |
| Kahler, F. A. | New Trier | 3 |
| Kinney, J. M. | Crane Col. | 7 |
| Kitch, C. E. | Oak Park | 7 |
| Laughlin, B. | Normal | 6 |
| Leach, E. S. | Evanston | 5 |
| Leckrone, Chas. | Lake View | 6 |
| MGill, R. W. | Proviso | 1 |
| Marks, F. R. | Lewis | 2 |
| Miller, O. M. | Hyde Park | 2 |
| Myers, G. W. | U. of C. | 5 |
| Newell, M. O. | Evanston | 5 |
| Owen, E. W. | Oak Park | 7 |
| Palser, C. I. | Armour | 1 |
| Piety, J. C. | Crane | 3 |
| Pyle, J. O. | Harrison | 2 |
| Runge, F. W. | Evanston | 1 |
| Sawyer, C. W. | Pullman | 1 |
| Schreiber, E. W. | Proviso | 7 |
| Sohwede, C. W. | Senn | 2 |
| Skinner, J. K. | Senn | 2 |
| Snyder, W. A. | New Trier | 2 |
| Staley, G. C. | Parker | 2 |
| Stokes, C. N. | New Trier | 1 |
| Taylor, G. G. | Deerfield | 4 |
| Thomas, B. J. | Lane | 2 |
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| Auble, J. L. | Proviso | 2 |
| Arnold, E. E. | The Pelhams | 1 |
| Bradley, A. P. | Evanston | 1 |
| Brown, W. L. | New Trier | 1 |
| Cable, W. J. | Austin | 1 |
| Chandler, H. W. | Oak Park | 4 |
| Clymer, F. P. | Waukegan | 4 |
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| Isenbarger | Crane Col. | 1 |
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| Nuttall, J. T. | Crane | 3 |
| Nyberg, J. A. | Hyde Park | 5 |
| Palmer, C. E. | Glenbard | 2 |
| Parson, L. B. | Evanston | 1 |
| Phillips, Guy | Thornton | 3 |
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| Schaefer, A. F. | Waukegan | 1 |
| Spitler, O. R. | Austin | 5 |
| Willis, U. G. | Pullman | 1 |

—[Compiled by Edwin W. Schreiber, Recording Secretary, Proviso, October 23, 1924.

## MILLIONS OF HORSEPOWER IN SOUTHERN RIVERS.

From 2,125,000 to 3,750,000 horsepower are running down the mountain sides of southeastern United States, the World Power Conference at London, was told by W. S. Lee, vice president and chief engineer of the Southern Power Company. There are now six large power companies operating in this region in addition to many smaller ones. Last year the combined out put of the larger companies was 2,918,000,000 kilowatt hours.

The Muscle Shoals plant of the United States Government when in full operation will add fifty per cent. to the present output of those companies Mr. Lee said. These power companies are interconnected by transmission lines, making a southeastern superpower system. As early as 1916 and on several occasions since, serious interference with public utilities and private industries have been avoided by the use of the interconnecting lines of the co-operating companies.—[*Science Service.*

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## BOOKS RECEIVED.

Junior High School Mathematics, First Course, by William Ledley Vosburgh, Teachers College, Boston, Mass.; Frederick William Gentleman, Mechanic Arts High School, Boston, Mass.; Jasper O. Hassler, University of Oklahoma. Pages VII plus 228. 13x19¼ Cm. Cloth, 1924. The Macmillan Co., New York.

Junior High School Mathematics, Second Course, by William L. Vosburgh, Teachers College, Boston, Mass.; Frederick W. Gentleman, Mechanic Arts High School, Boston, Mass.; Jasper O. Hassler, University of Oklahoma. Pages X plus 255. 13x19¼ Cm. Cloth, 1924. The Macmillan, Co., New York.

Animal Husbandry for Schools, by Merritt W. Harper, Cornell University. Pages IX plus 615. 14x20½ Cm. Cloth, 1924. The Macmillan Co., New York.

Elementary Accounting by Hiram T. Scovill, University of Illinois., Pages XI plus 435. 15x23 Cm. Cloth, 1924. D. C. Heath & Co., Chicago.

Health as a Heritage, by Ralph E. Blount, Waller High School, Chicago. Pages IX plus 44. 13x19¼ Cm. Cloth, 1924. Allyn & Bacon, Chicago.

Fungi and Human Affairs, by W. A. McCubbin, Harrisburg, Pa. Pages VIII plus 111. 13½x19 Cm. Cloth, 1924. World Book Co., Chicago.

Bookkeeping and Accounting, by Harlan E. Read and Charles J. Harvey. Pages XIV plus 207. 18x24½ Cm. The Macmillan Co., New York.

New Biology, by W. M. Smallwood, Syracuse University; Ida L. Reveley, Wells College; Guy A. Bailey, Geneseo State Normal School. Pages XIX plus 37 plus 704. 13x19¼ Cm. Cloth, 1924. Allyn and Bacon, Chicago.

Practical Calculus for Home Study, by Claude I. Palmer, Armour Institute of Technology. Pages XX plus 443. 12¼x20½ Cm. Leather, 1924. McGraw-Hill Book Co., Inc., New York.

Keeping Up With Science, by Edwin E. Slosson, Washington. Pages XIV plus 355. 14x21 Cm. Cloth 1924. Harcourt, Brace & Co., New York.

Early Steps in Science, by Hanor A. Webb, George Peabody College for Teachers; John J. Didcoct, George Peabody College for Teachers Pages XV plus 691. 13x19½ Cm. Cloth, 1924. D. Appleton & Co. New York.

Second Course in Algebra, by Edward I. Edgerton, Dickinson High School, Jersey City, N. J.; Perry A. Carpenter, West High School, Rochester, N. Y. Pages VII plus 461. 13x19¼ Cm. Cloth, 1924. Allyn & Bacon, Chicago.

Physiology and Hygiene, Francis M. Walters, State Teachers' College, Warrensburg, Mo. Pages VIII plus 426. 13½x19 Cm. Cloth, 1924. D. C. Heath & Co., New York.

Elements of Physics, by F. W. Merchant, Chief Director of Education for Ontario; G. A. Chant, University of Toronto. Pages VII plus 546. 14x20½ Cm. Cloth, 1924. Henry Holt & Co., New York.

A Chapter in American Education, by Ray Palmer Baker, Rensselaer Polytechnic Institute. VIII plus 170 pages. 13x19¼ Cm. Cloth, 1924. Charles Scribner's Sons, New York.

Accounting Principles and Bookkeeping Methods, Volume II, by H. A. Finney, Northwestern University. Pages III plus 248. 16½x25 Cm. Cloth, 1924. Henry Holt & Co., New York.

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Science and Mathematics, State Course of Study for Secondary Schools, by Dr. Alfred D. Kinsey; E. E. Ramsey; Herbert S. Vorhees; B. B. Horton; Charles L. Brosey, Indianapolis. Pages 182. 22½x15 Cm. Paper, 1923. Wm. B. Burford, Indianapolis.

Visual Education, by Frank N. Freeman. Pages VIII plus 391. 15½x23½ Cm. Cloth, 1924. University of Chicago Press, Chicago.

The Recent Development of Physical Science, by William C. D. Whetham, Trinity College. Pages XIV plus 313. 13½x20 Cm. Cloth. 1924. Price, $3.00. P. Blakiston's Son & Co., Philadelphia.

## BOOK REVIEWS.

*Applied Chemistry, by Ira D. Garard, Ph. D. Prof. of Chem. in New Jersey College for Women, State Univ. of New Jersey.* 1st edition. pp VII plus 496. 13½x19x3.5 cm 28 figures and diagrams. Cloth. 1924. Macmillan.

A text for college students to follow a year of general chemistry. Enough organic chemistry is included so that those who have not had a course in organic chemistry may yet use the text to advantage. Many laws of chemistry and many chemical principles are referred to as their applications are taken up in the course of the work. The chapter headings show that the earlier chapters are given to the consideration of air and water, combustion, forms of energy and their chemical applications, then come some six or seven chapters on food chemistry, then a chapter on Colloid chemistry, one on cleansing agents, another on textiles, dying and bleaching, then six on various industrial subjects such as leather, rubber, paints, etc. F. B. W.

*Powers General Chemistry Test, by S. R. Powers, Ph. D., Associate Professor of Natural Science, Teachers College, Columbia University.* 1st edition of revised form. Manual of directions, two test forms with keys and class record form. An entirely objective test of accomplishment. Requires 45 minutes to administer. Norms based upon 3000 cases are furnished. Put up in packages of 25. Copyright 1924. $1.30 for set of 25. World Book Co., Yonkers-on-Hudson or 2126 Prairie Ave., Chicago, Ill.

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*The Recent Development of Physical Science, by William C. D. Whetham, Trinity College.* Pages XIV plus 313. 13½x20 cm. Cloth, 1924. Price $3.00. P. Blackston's Son & Co., Philadelphia, Pa.

It has been a period of fifteen years since the last edition of this splendid work came from the press. In the meantime, two very important theories of physics have come on the field of action, namely, the principle of relativity and the Quantam theory. In order to make the book confirm in every respect with these new theories, it has been necessary to revise the book practically completely.

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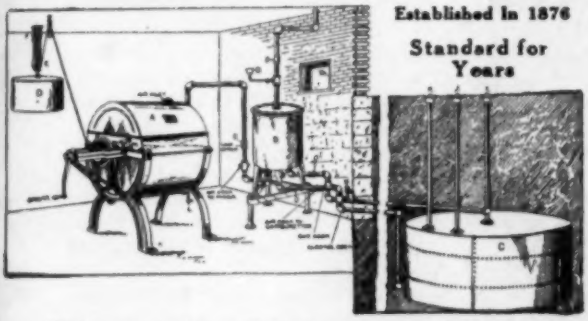

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*Physiology and Hygiene, by Francis M. Walters, State Teachers' College, Warrensburg, Mo.* Pages VIII plus 426. Cloth, 1924. D. C. Heath & Co., Chicago, Ill.

This is a revision of Walters' Physiology and Hygiene which came from the press several years ago. He has brought it down to date with many additions and new insertions. He stresses the method of right living by means of correct habits in caring for one's body in all of its aspects.

By right living, he means to have it understood that one should conduct himself and act in such manner as will cause the bodily organs and processes not to be destroyed by any evil or malicious habits.

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It is printed on paper that is not highly calandered, in ten point type. It is well indexed and is a good book to put in the hands of the high school pupils. C. H. S.

*New Biology, W. M. Smallwood, Syracuse University; Ida L. Reveley, Wells College, Guy A. Bailey, Geneseo State Normal School.* Pages XIX plus 37 plus 704. 13x19¼ cm. Cloth, 1924. Allyn and Bacon, Chicago.

This book is one of the most cleverly written and splendidly equipped books that the reviewer has seen in many a day.

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*Health as a Heritage, by Ralph E. Blount, Waller High School, Chicago.* Pages IX plus 44. 13x19¼ cm. Cloth, 1924. Allyn & Bacon, Chicago.

This splendid little book on health as a heritage comes out at a time when there is a great demand for a presentation of matters to which this pertains. It places before the pupil in language as good as possible the fundamental principles of sex. It presents the pit-falls to which young high-school people are subjected, and presents in a vivid manner the evils which may attend such matters, at the same time discussing remedies for them.

The illustrations are few and to the point. C. H. S.

*A Chapter in American Education, by Ray Palmer Baker, Rensselaer Polytechnic Institute.* Pages VIII plus 170. 13x19¼ cm. Cloth, 1924. Charles Scribner's Sons. New York.

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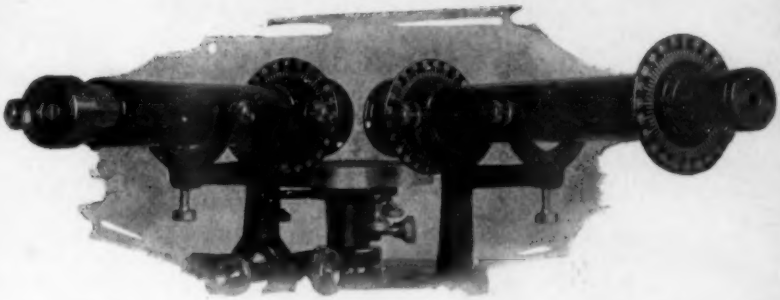

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*Elements of Physics, by F. W. Marchant and C. A. Chant, University of Toronto.* Pages VII plus 546. 14½x21½ cm. Cloth, 1924. Henry Holt & Co., New York.

This is a remarkably fine text from our Canadian friends. It is thoroughly up-to-date.

The matter is presented in a most interesting and clear way. The diction is fine.

Major paragraphs all begin with bold-faced type which tells of the matter that is to be discussed in those paragraphs. The book is splendidly illustrated by 631 cuts, most of which have been drawn for this particular work.

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It is a book that can be recommended for any high school class.

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There is a fine list of classified review problems found in the rear of the book. There is a splendid index at the end.

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*Laboratory Problems in Physics, by Angus L. Cavanagh, Harding High School, Los Angeles, California, and Clyde M. Westcott, Hollywood High School, Los Angeles, California.* Pages VIII plus 127. 20½x27 cm. Cloth, 1924. $0.96. Ginn & Co., Chicago, Ill.

This is one of the most up-to-date high school manuals in physics that the reviewer has seen in a long time. It is adaptable to any first year text as well as to any high school course in physics.

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*Keeping Up With Science, by Edwin E. Slosson, Director of Science Service, Washington, D. C.* Pages XIV plus 355. 14x21 cm. Cloth, 1924. Harcourt, Brace & Co., New York.

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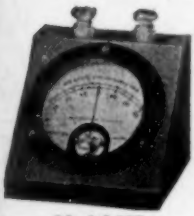

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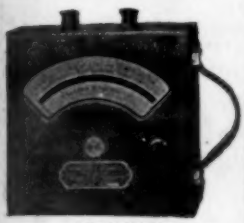

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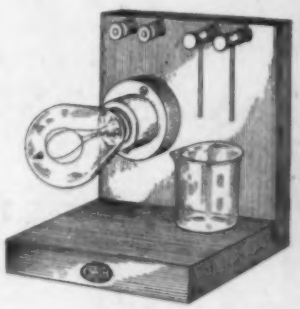

In operation, the beaker is raised till its contents surrounds the electrodes. If the solution is an electrolyte, the lamp, mounted at the left of the apparatus, lights instantly. The brilliance of the light indicates the extent to which electricity is conducted by the solution under test. At the same time, this lamp acts as a resistance unit to cut down the current to the proper stength.

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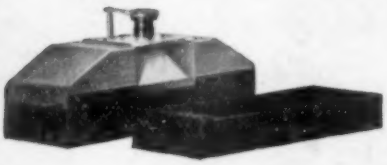

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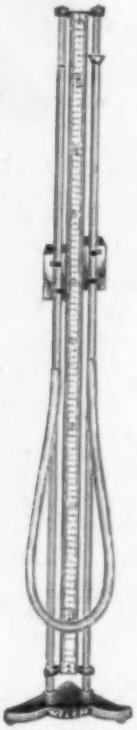

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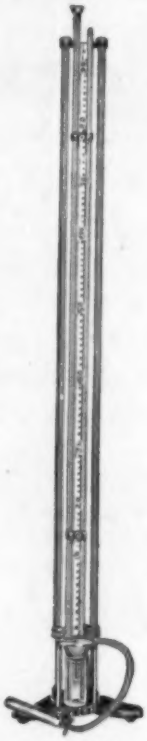

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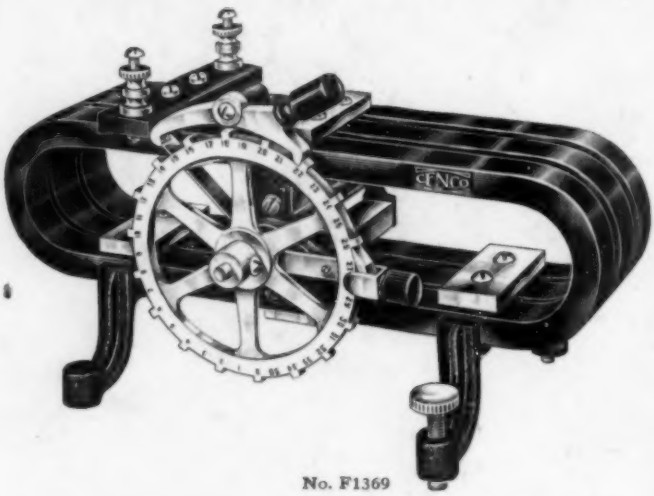


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